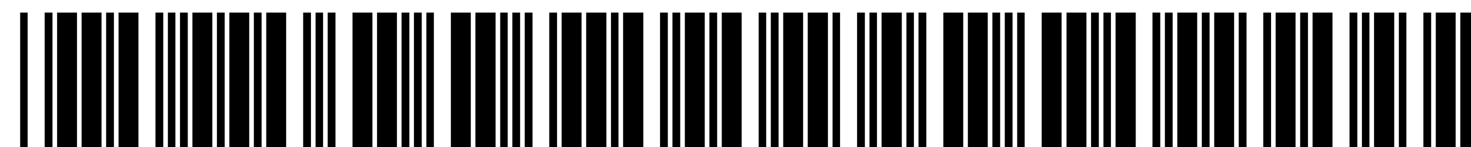
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(12) **United States Patent**
Okazaki et al.

(10) **Patent No.: US 7,221,002 B2**
(45) **Date of Patent: May 22, 2007**

(54) **LIGHT EMITTING ELEMENT, METHOD OF MANUFACTURING THE SAME, AND SEMICONDUCTOR DEVICE HAVING LIGHT EMITTING ELEMENT**

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(73) Assignee: **Kabushiki Kaisha Toshiba**, Kawasaki-shi (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/958,911**

(22) Filed: **Oct. 4, 2004**

(65) **Prior Publication Data**

US 2005/0040420 A1 Feb. 24, 2005

Related U.S. Application Data

(60) Division of application No. 10/417,873, filed on Apr. 17, 2003, now Pat. No. 6,825,502, which is a continuation of application No. 09/893,925, filed on Jun. 27, 2001, now abandoned.

(30) **Foreign Application Priority Data**

Jun. 30, 2000 (JP) 2000-200298

(51) **Int. Cl.**
H01L 29/22 (2006.01)

(52) **U.S. Cl.** **257/98**; 257/99

(58) **Field of Classification Search** 257/81, 257/85, 87, 91, 98–99
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,342,944 A * 8/1982 SpringThorpe 313/499
5,578,162 A 11/1996 D'Asaro et al. 148/33.4
5,625,202 A 4/1997 Chai
5,760,422 A * 6/1998 Ishinaga 257/94
5,917,202 A * 6/1999 Haitz et al. 257/98
5,977,566 A 11/1999 Okazaki et al.
5,990,500 A 11/1999 Okazaki
6,310,364 B1 10/2001 Uemura 257/100

FOREIGN PATENT DOCUMENTS

JP 08-64872 3/1996
JP 08-288551 11/1996
JP 11-008410 1/1999
JP 11-191641 7/1999
JP 11-229168 8/1999
JP 11-298040 10/1999
JP 2000-164928 6/2000

* cited by examiner

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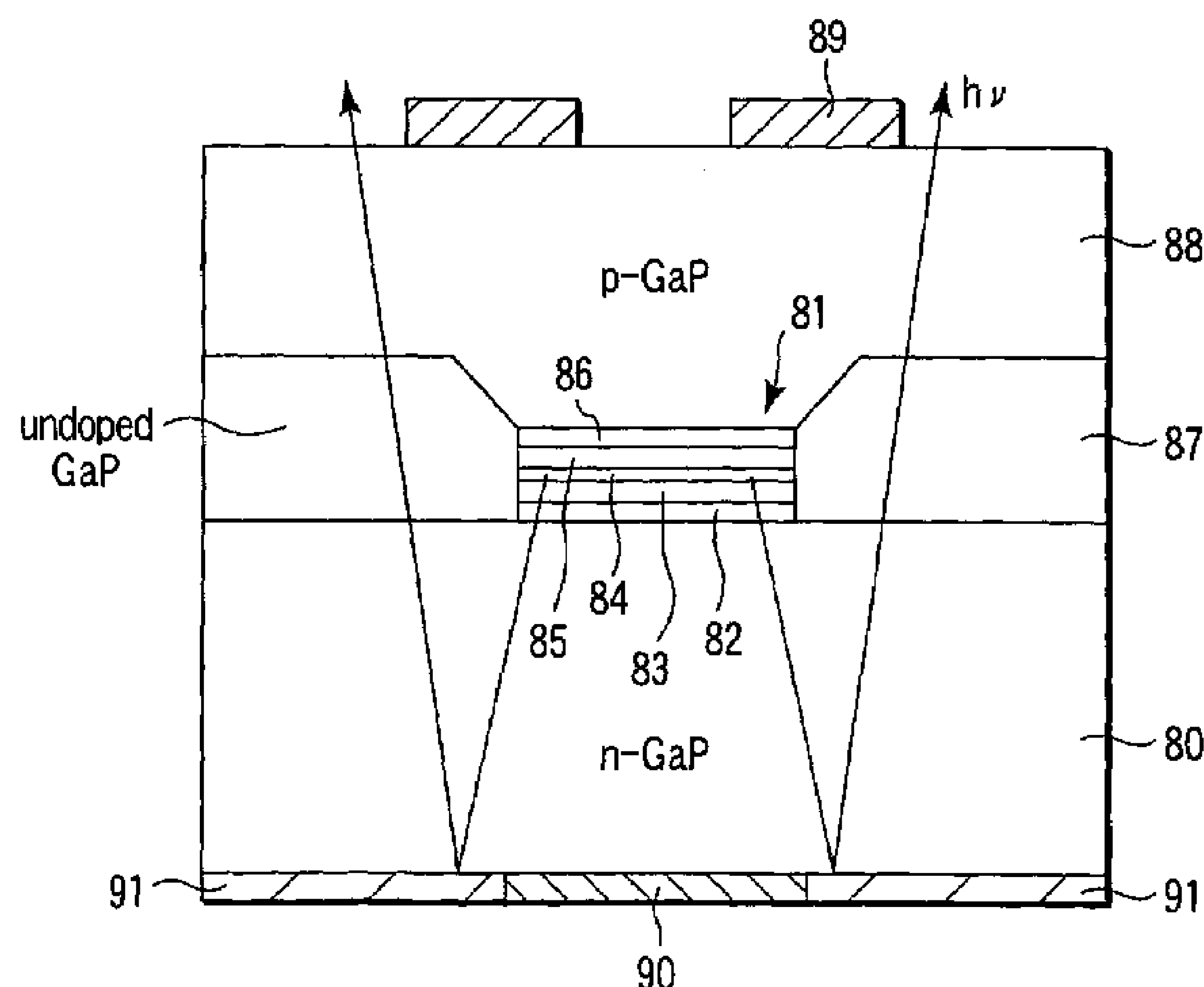
(74) *Attorney, Agent, or Firm*—Hogan & Hogan LLP

(57) **ABSTRACT**

An InGaN active layer is formed on a sapphire substrate. A p-side electrode is formed on the InGaN active layer to supply an electric current to this InGaN active layer. The p-side electrode includes ① an Ni layer for forming an ohmic contact with a p-GaN layer, ② an Mo layer having a barrier function of preventing diffusion of impurities, ③ an Al layer as a high-reflection electrode, ④ a Ti layer having a barrier function, and ⑤ an Au layer for improving the contact with a submount on a lead frame. The p-side electrode having this five-layered structure realizes an ohmic contact and high reflectance at the same time.

8 Claims, 12 Drawing Sheets



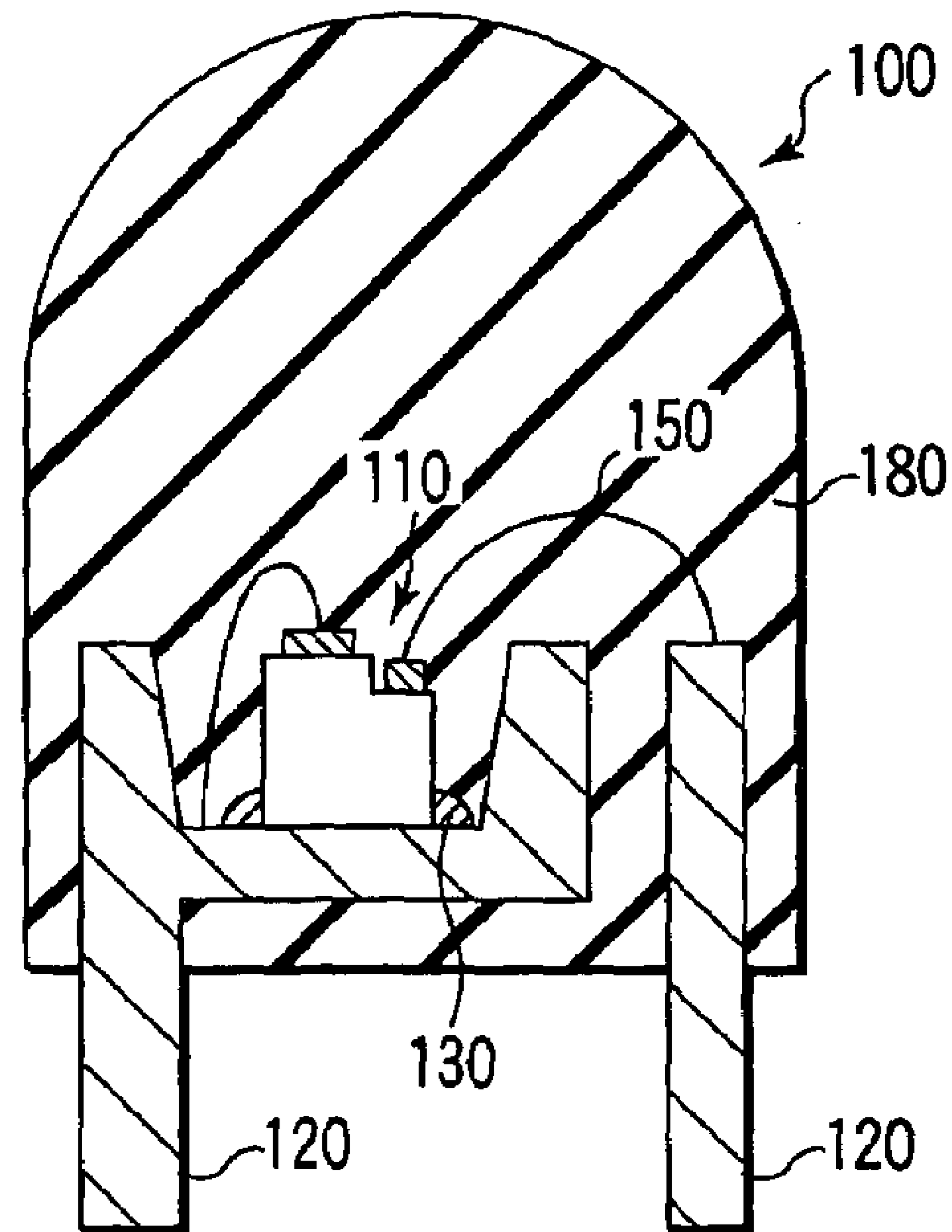


FIG. 1
PRIOR ART

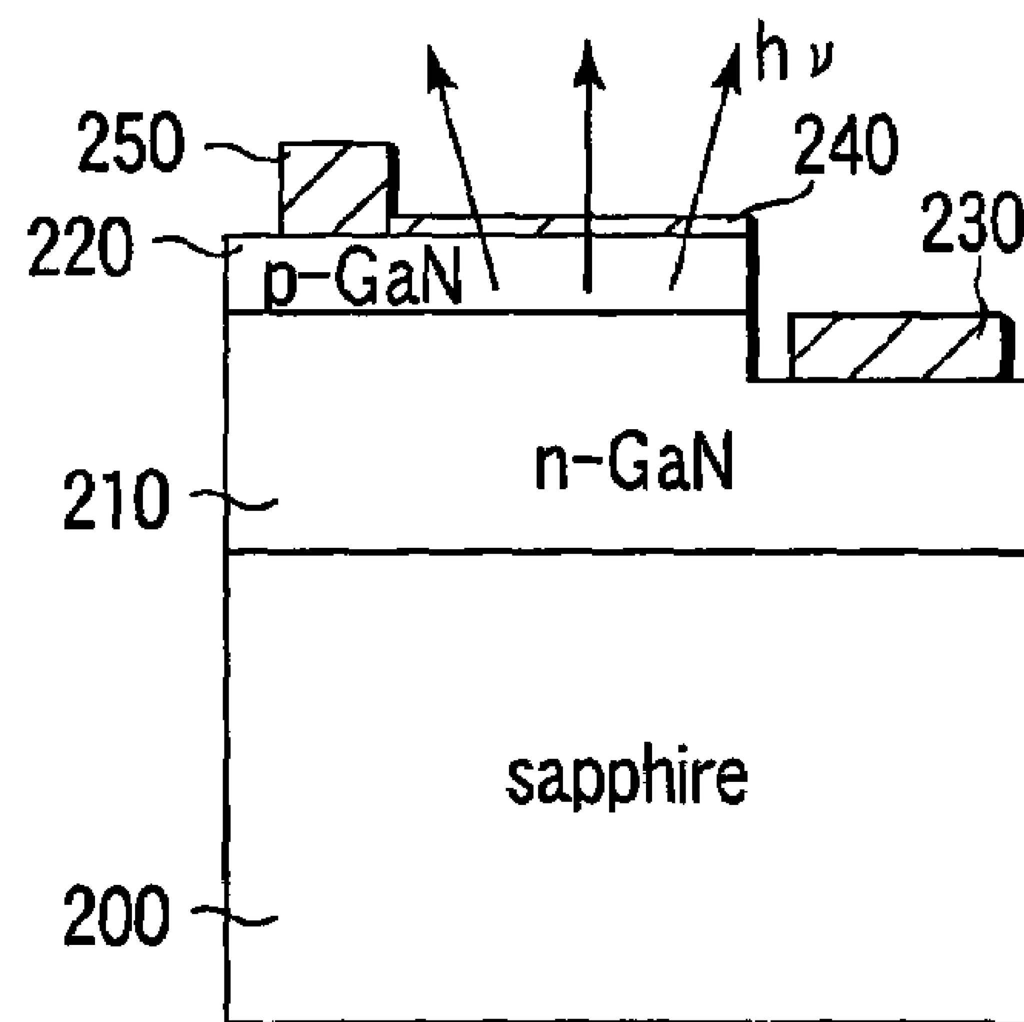


FIG. 2
PRIOR ART

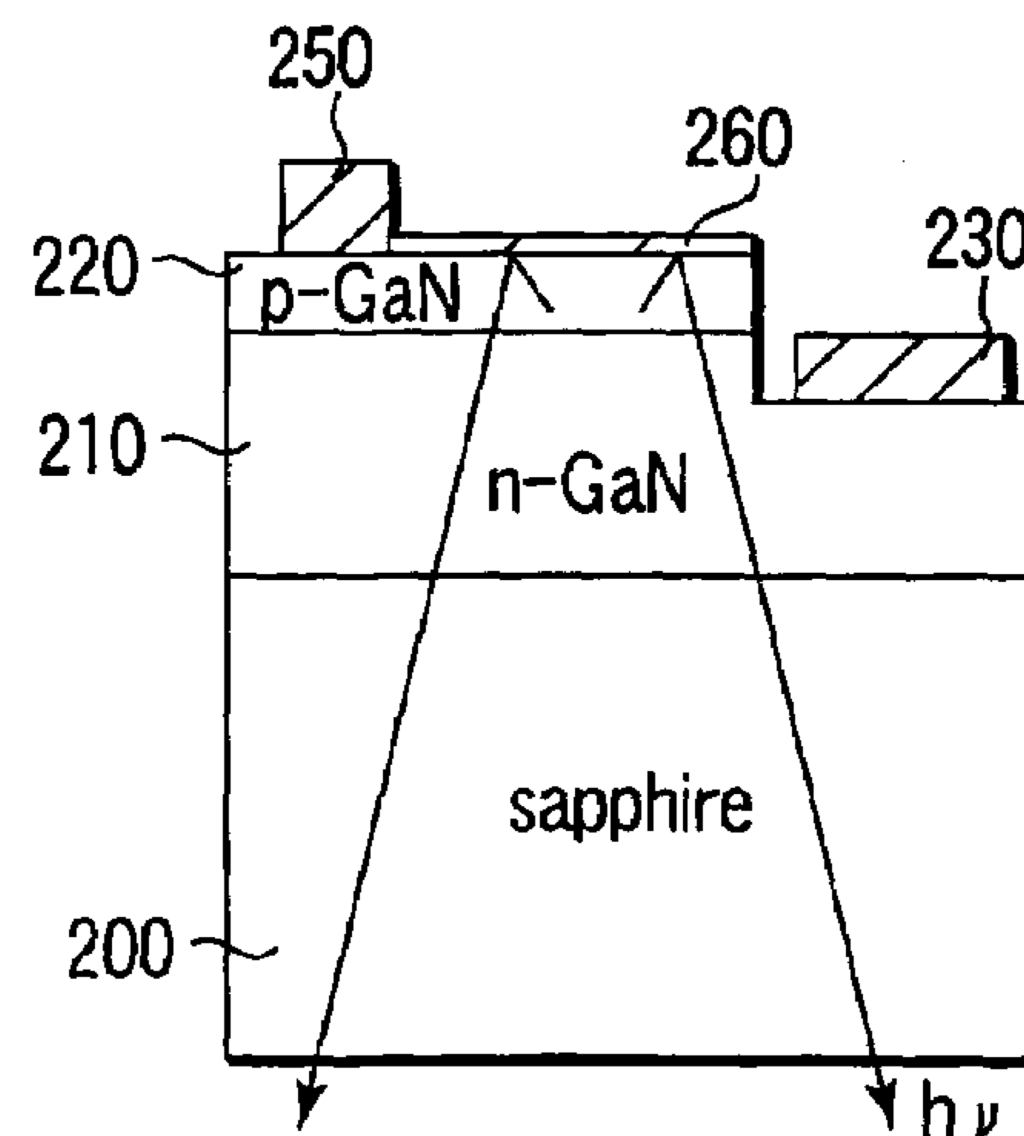


FIG. 3
PRIOR ART

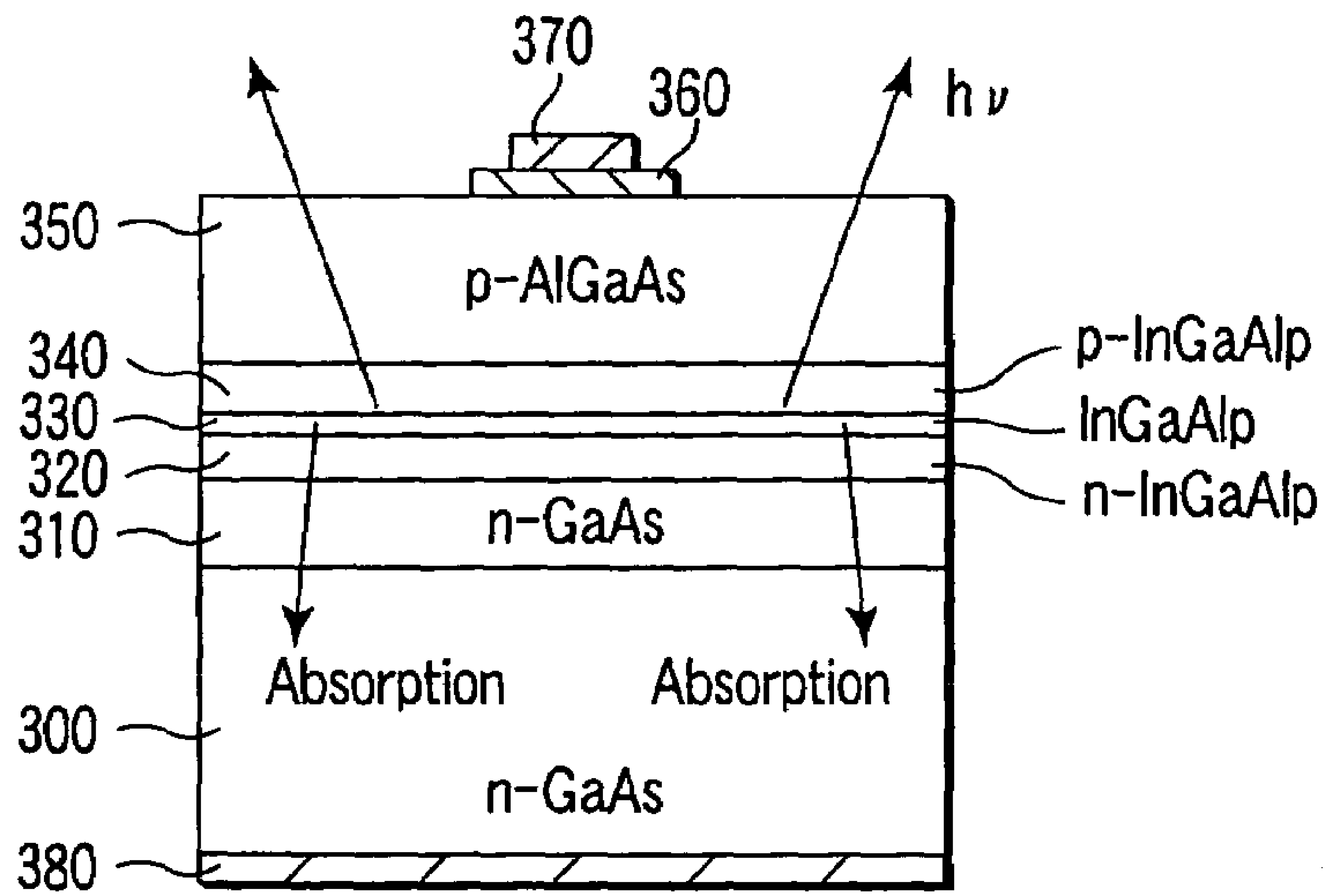


FIG. 4
PRIOR ART

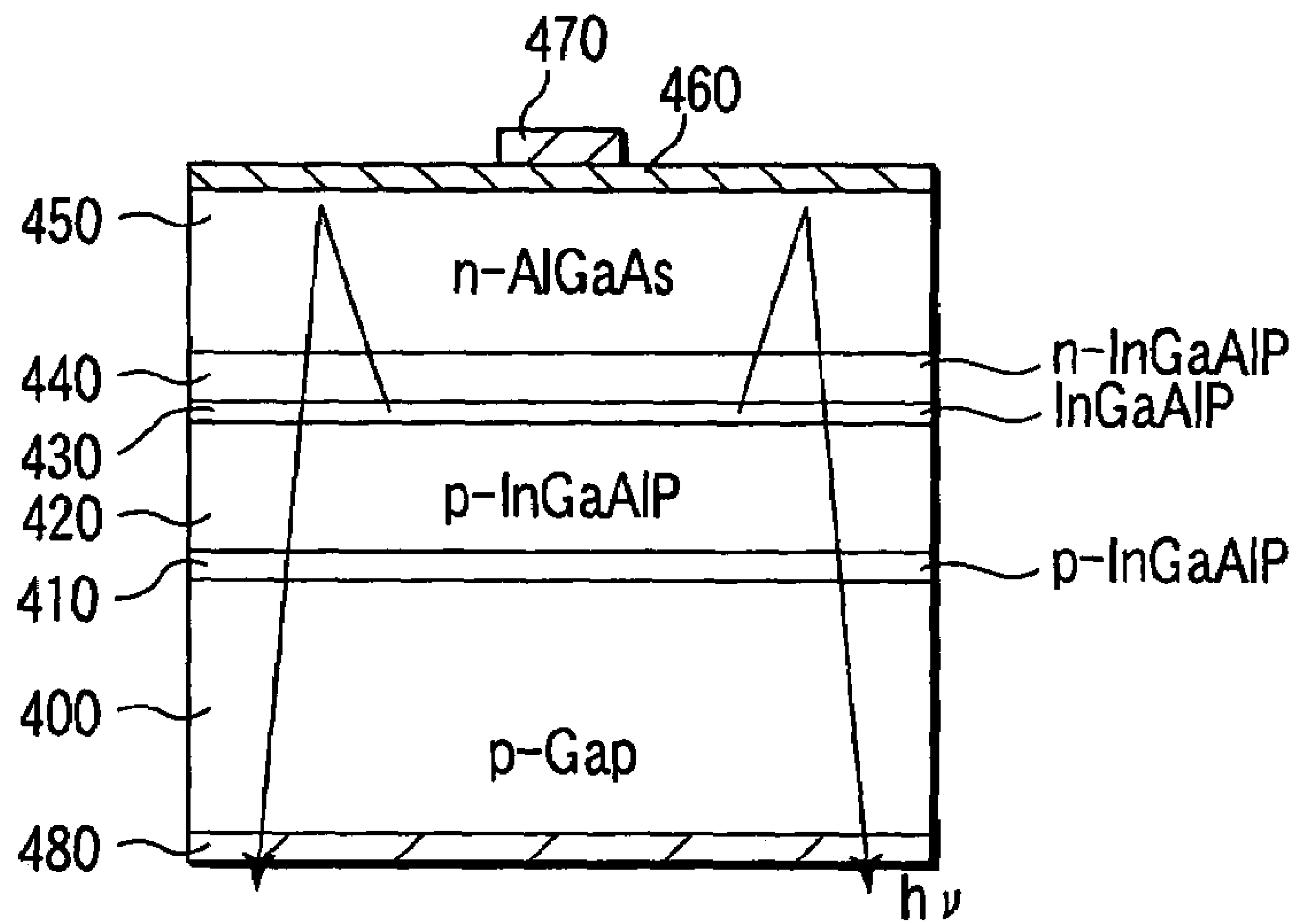


FIG. 5
PRIOR ART

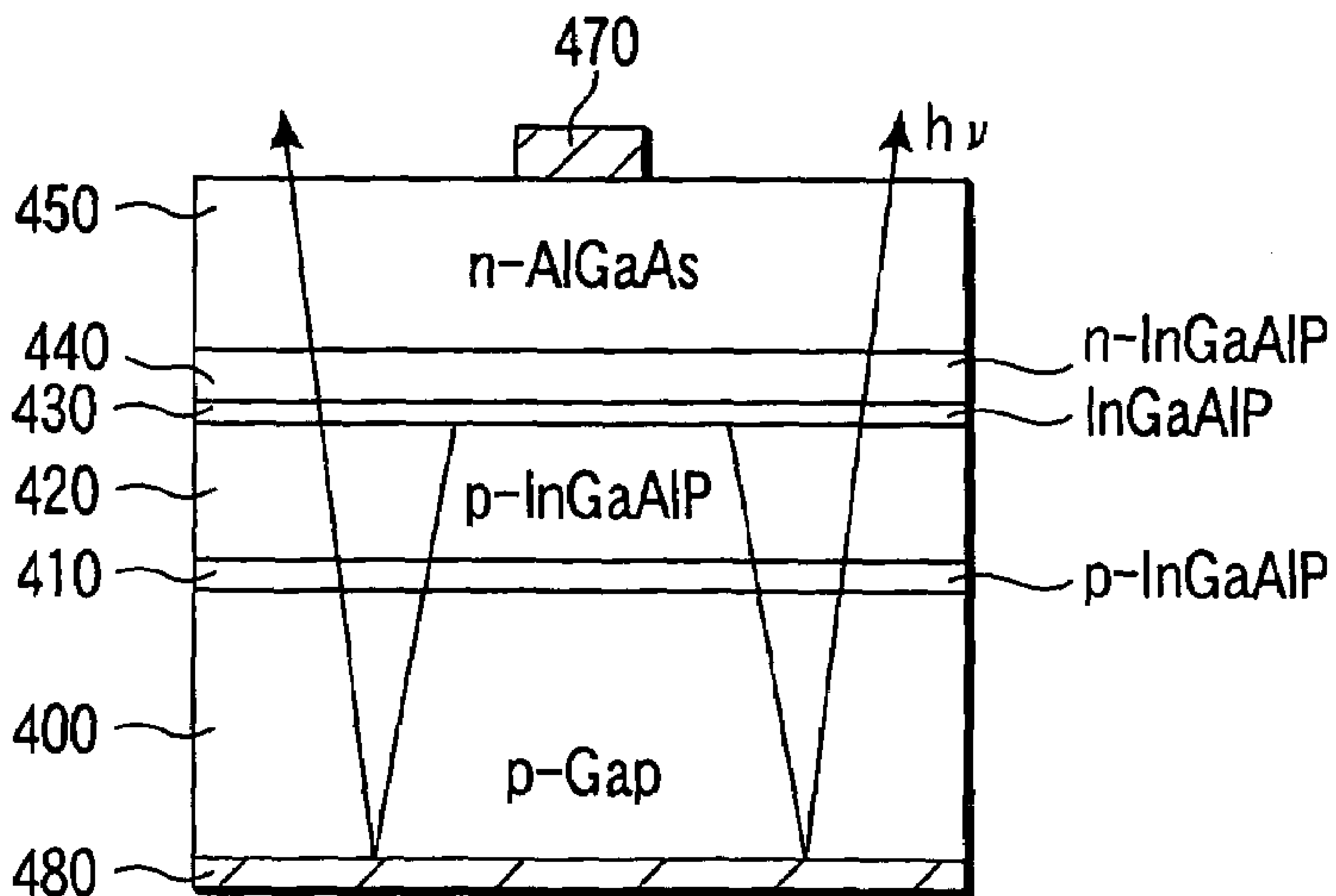


FIG. 6
PRIOR ART

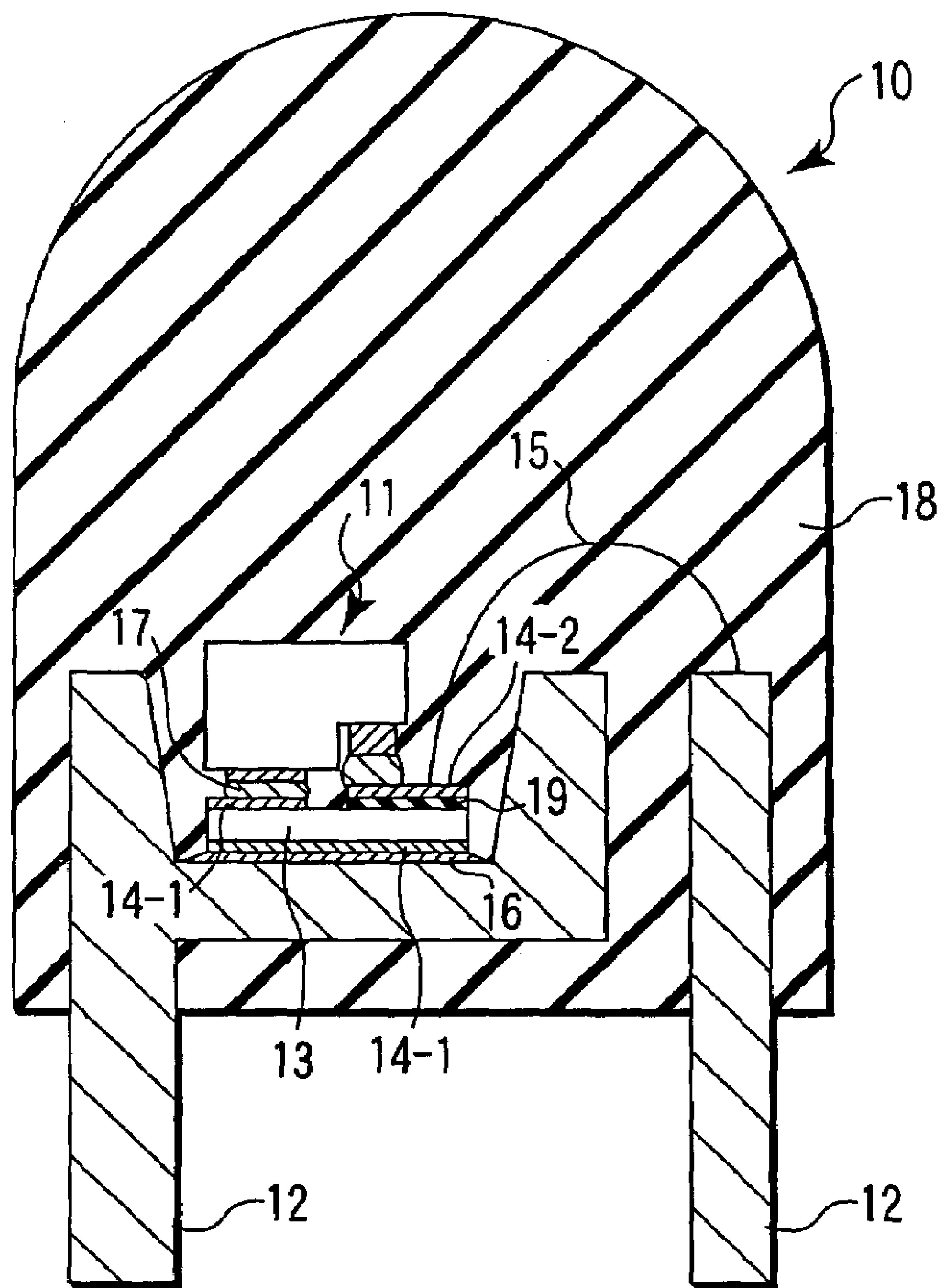


FIG. 7

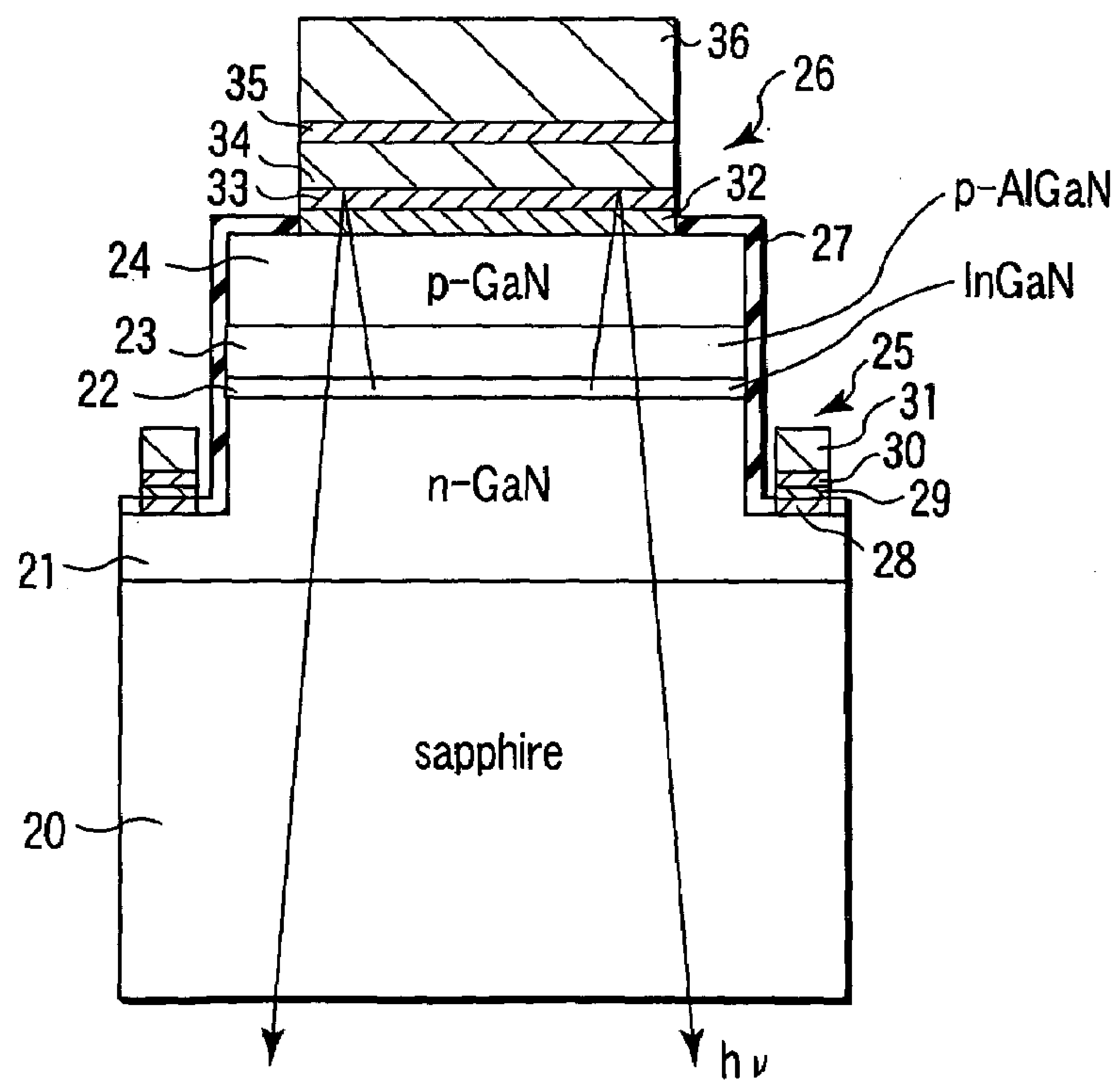


FIG. 8

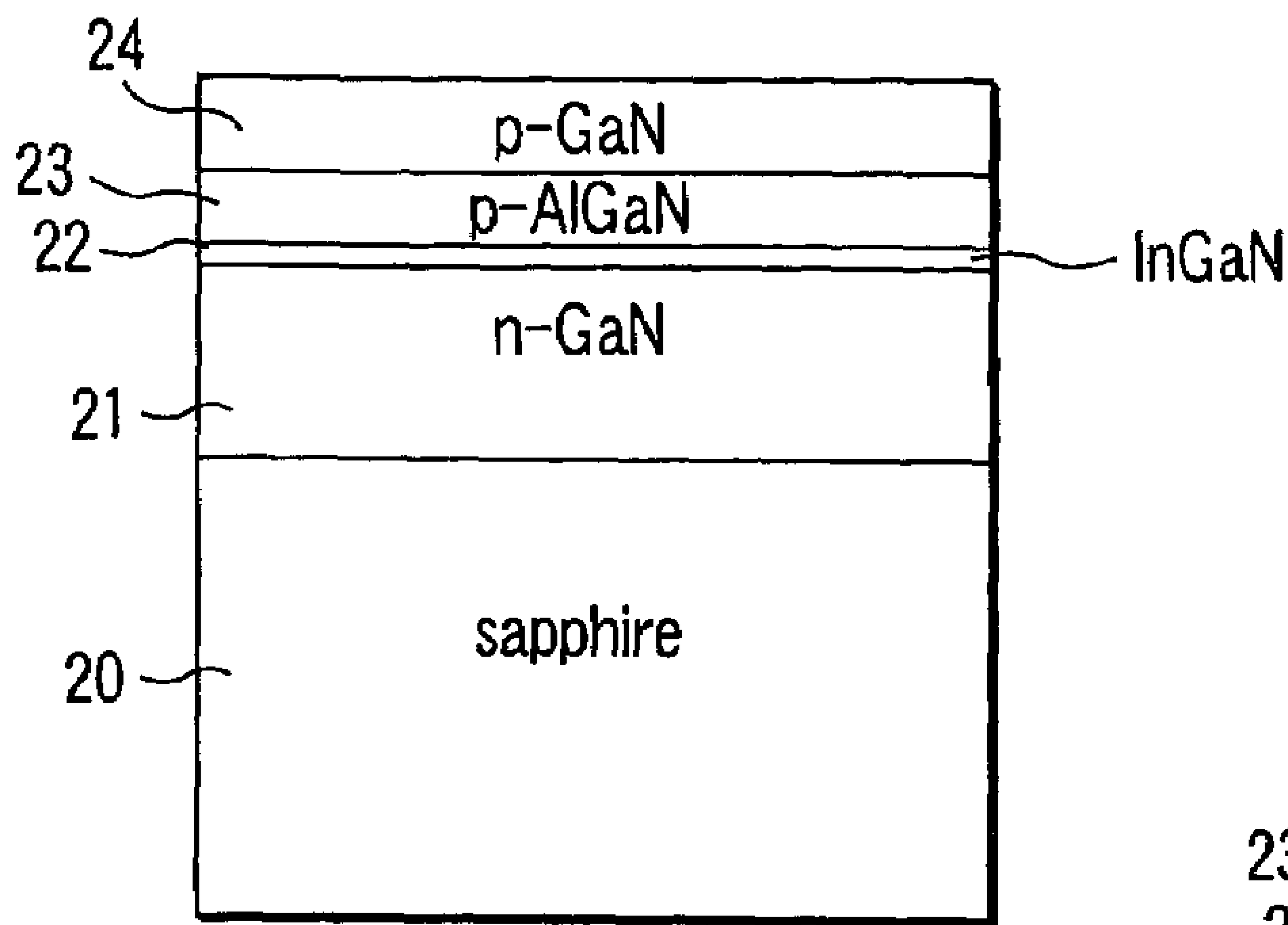


FIG. 9

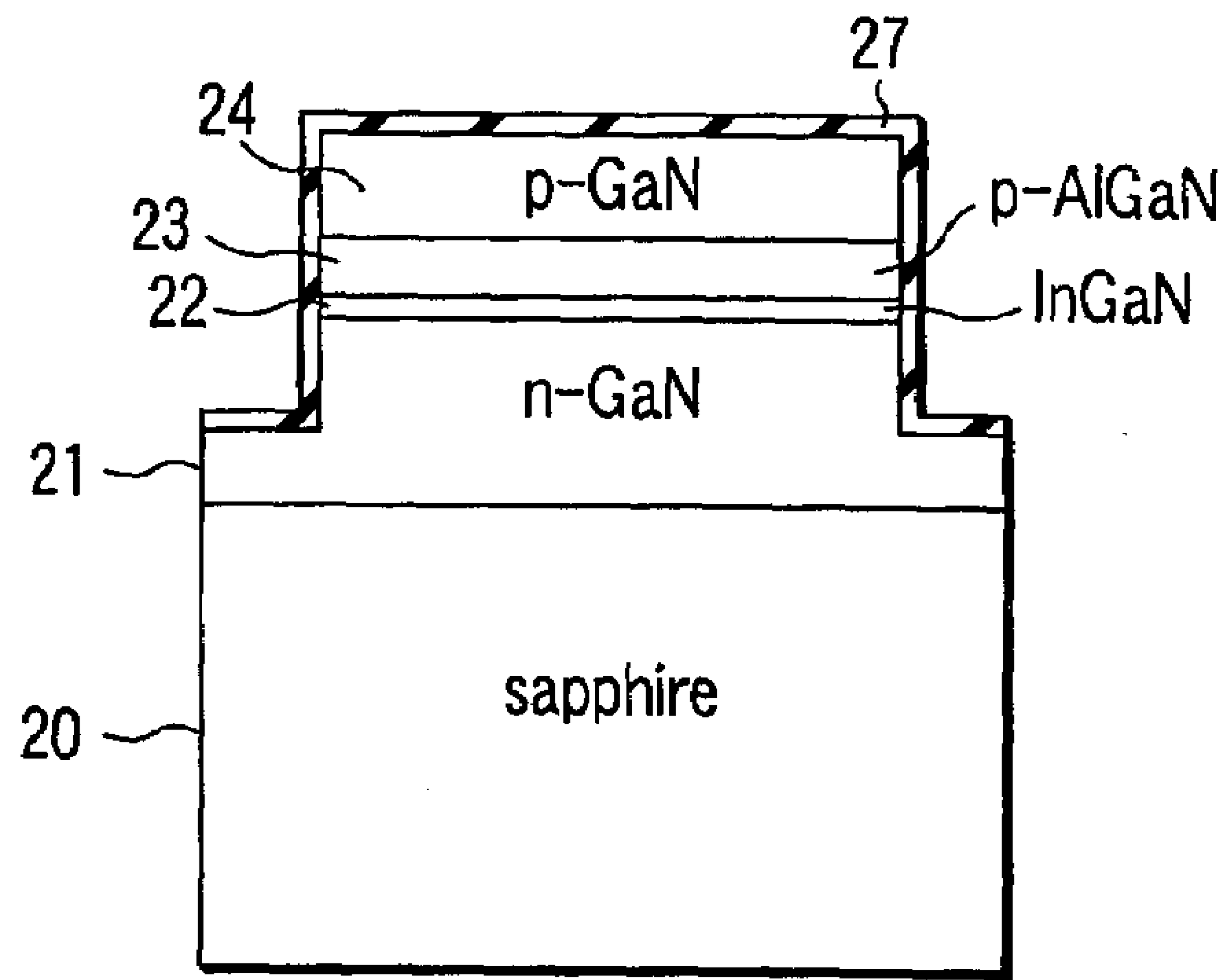


FIG. 10

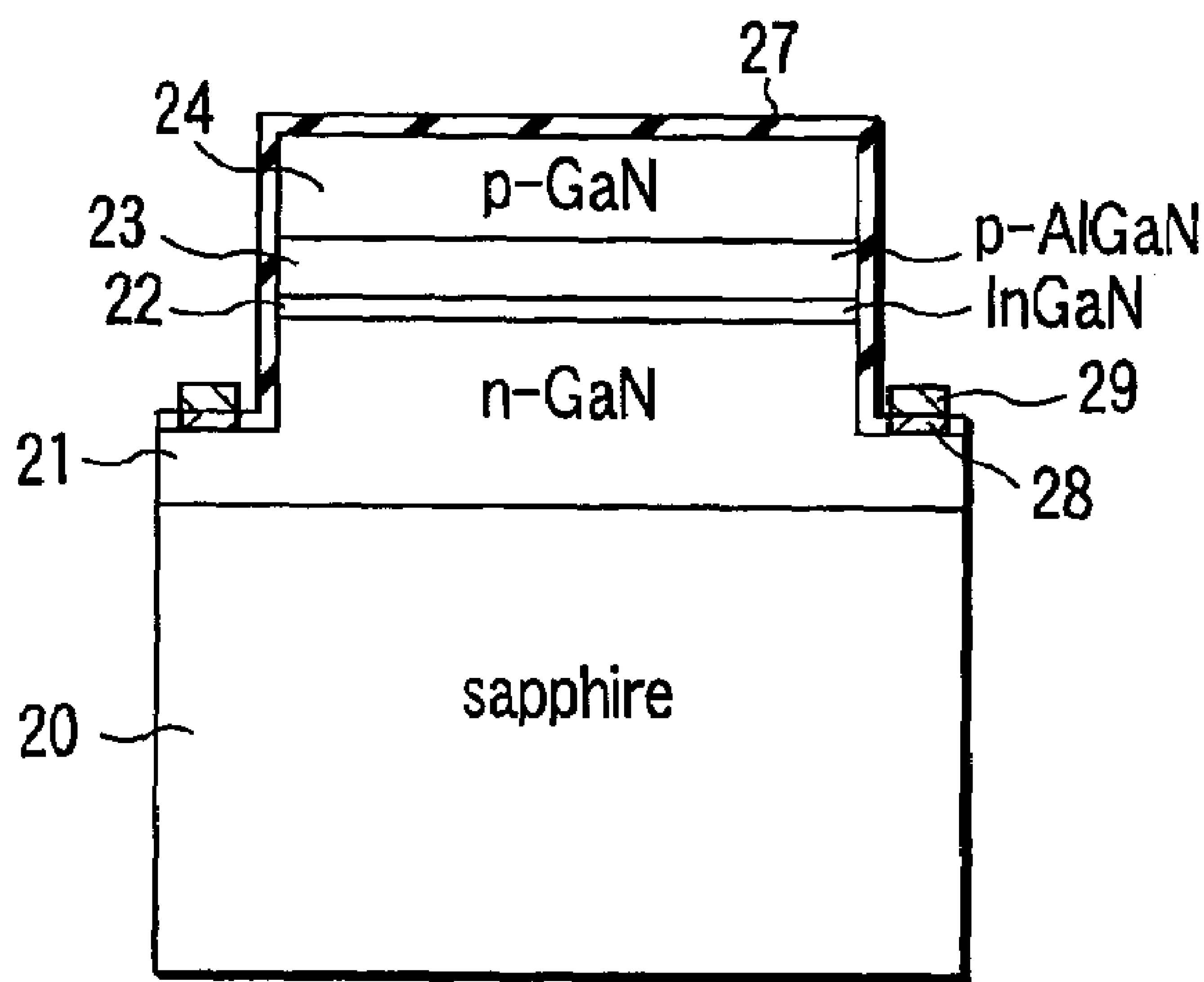


FIG. 11

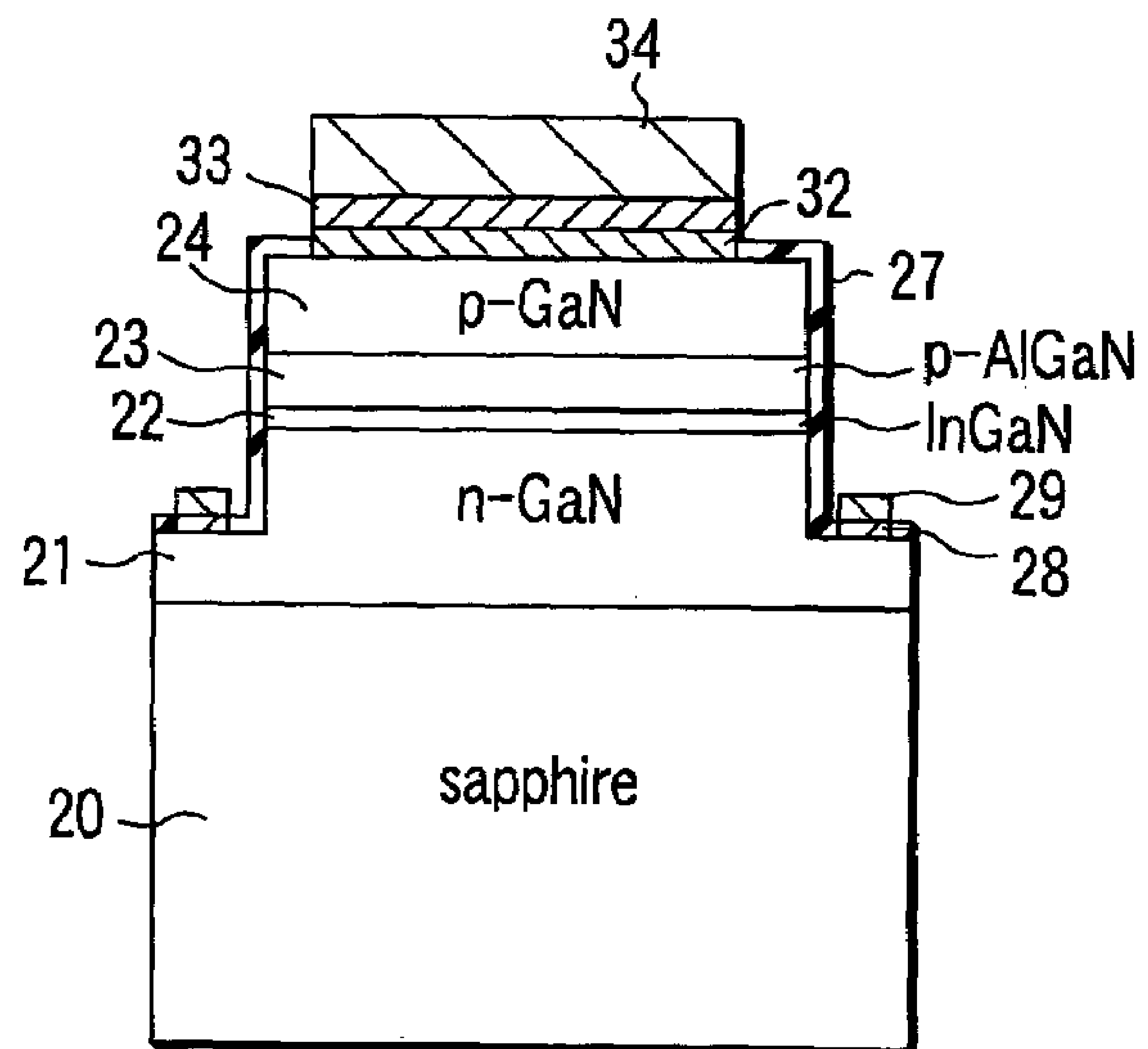


FIG. 12

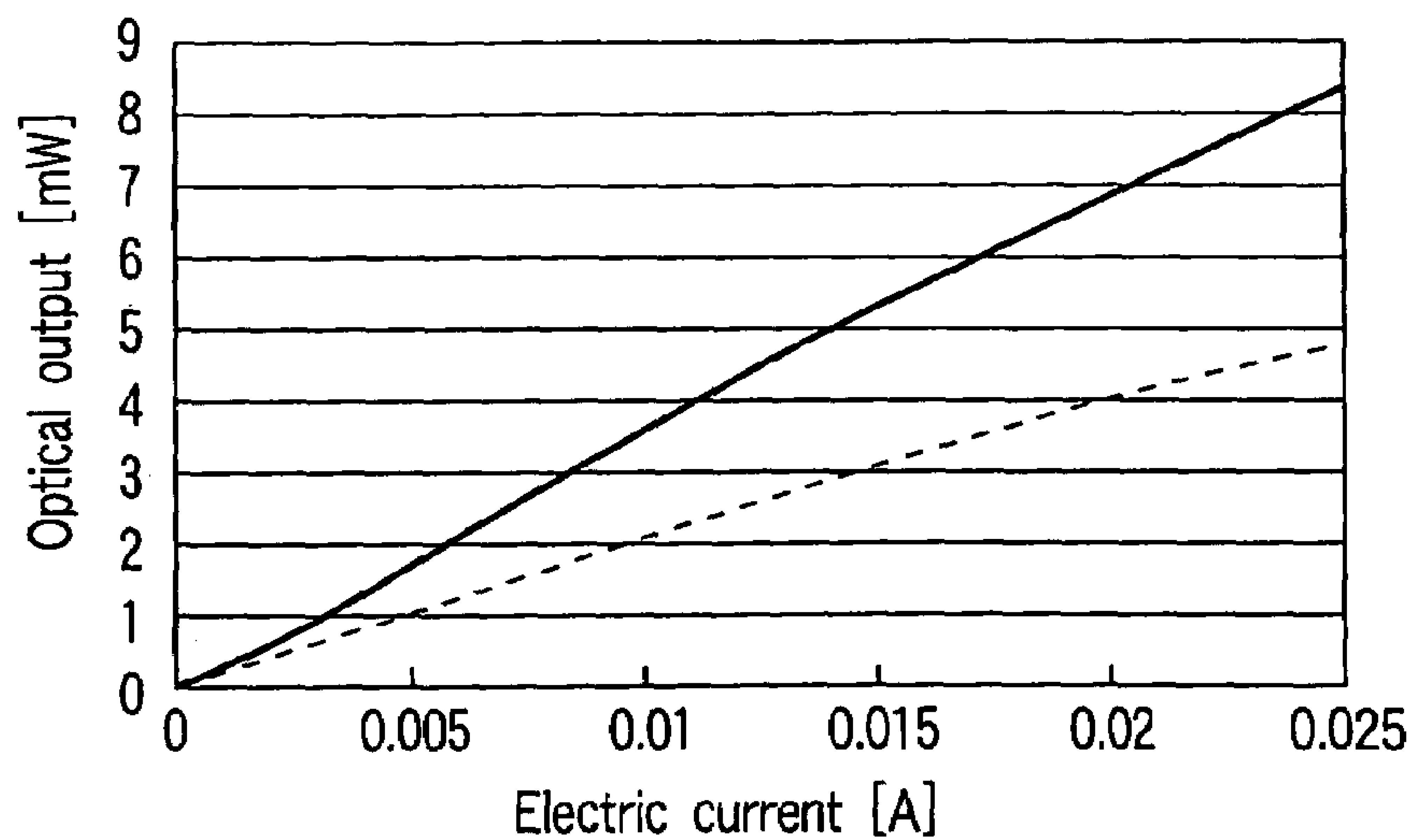


FIG. 13

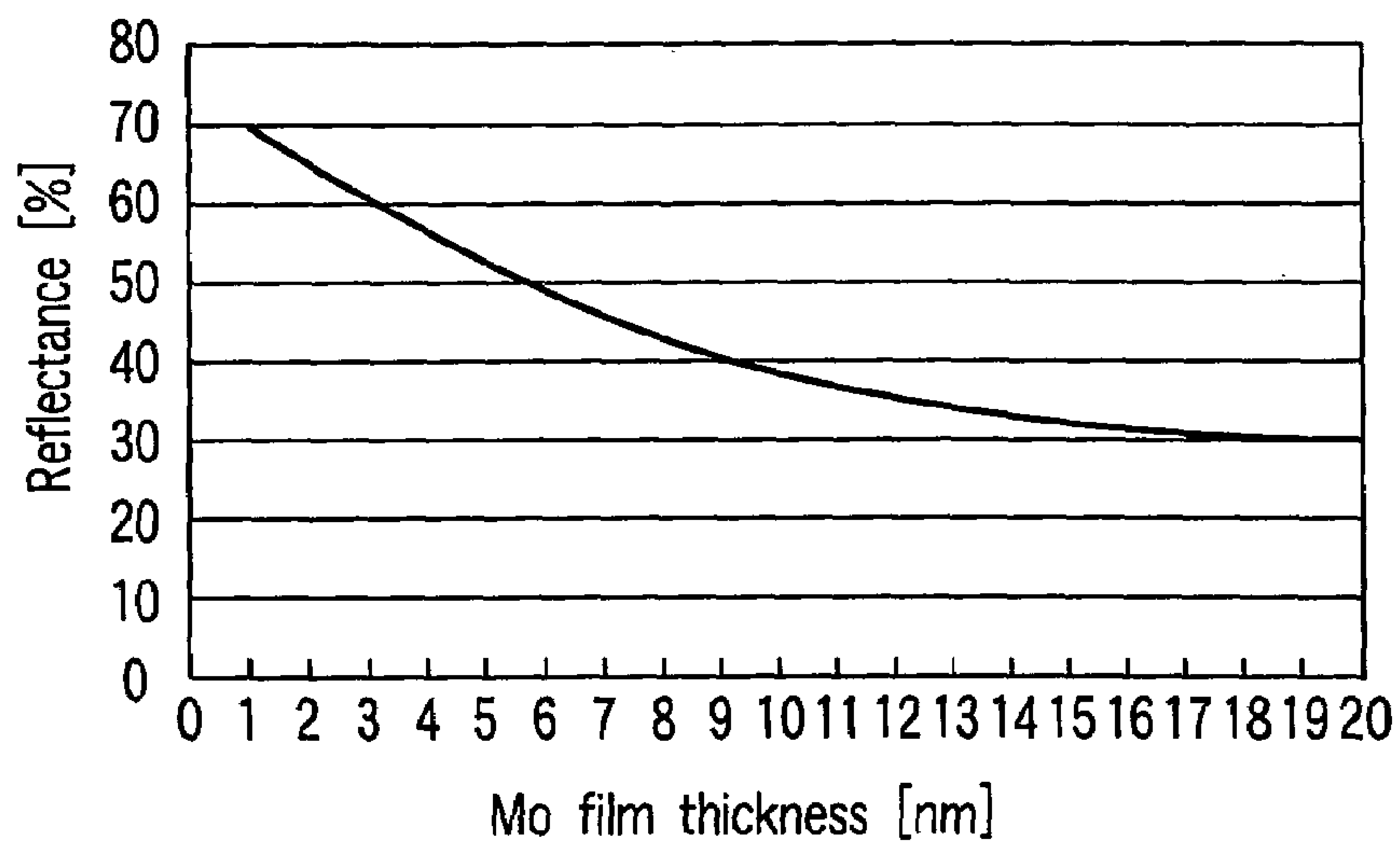


FIG. 14

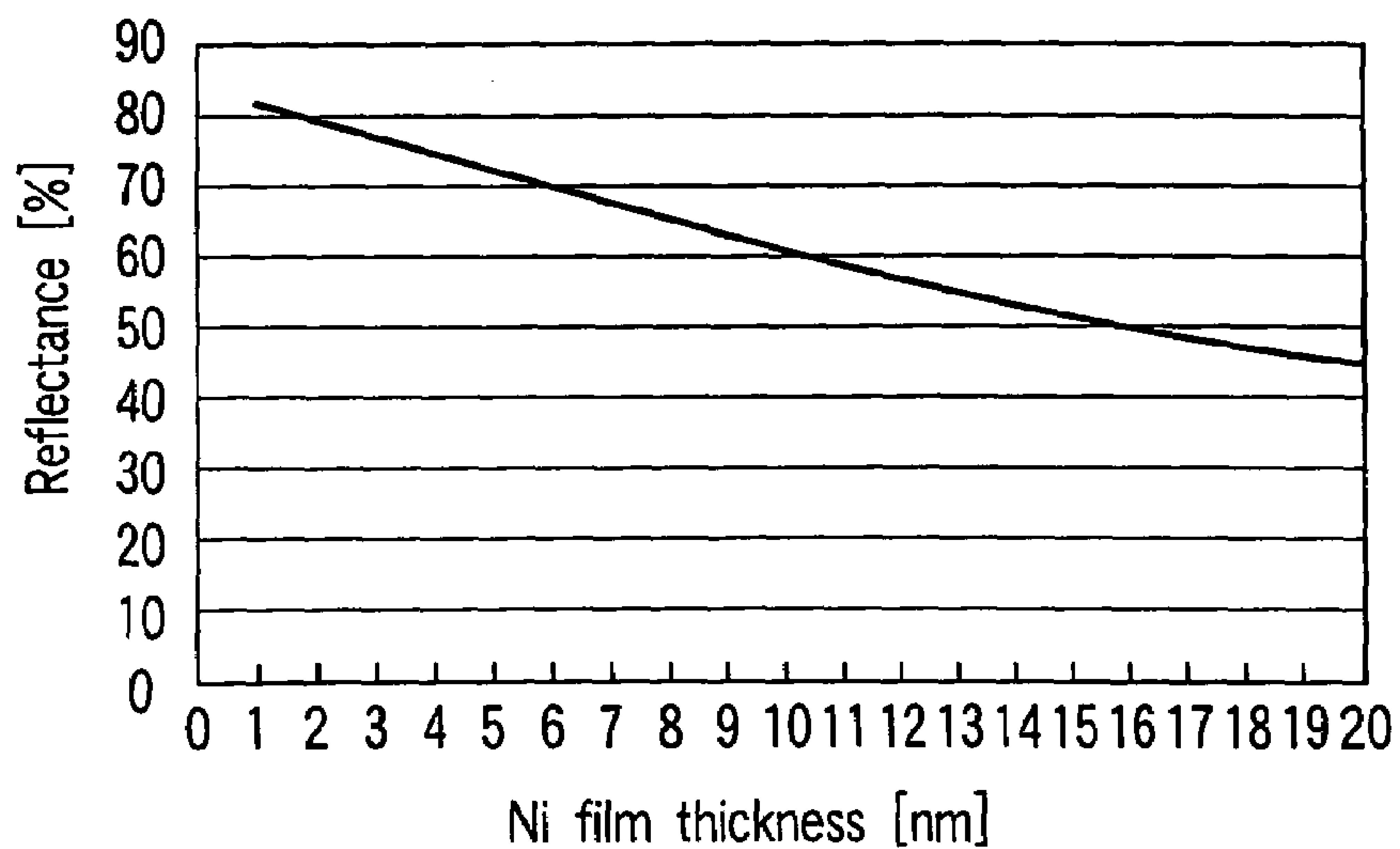


FIG. 15

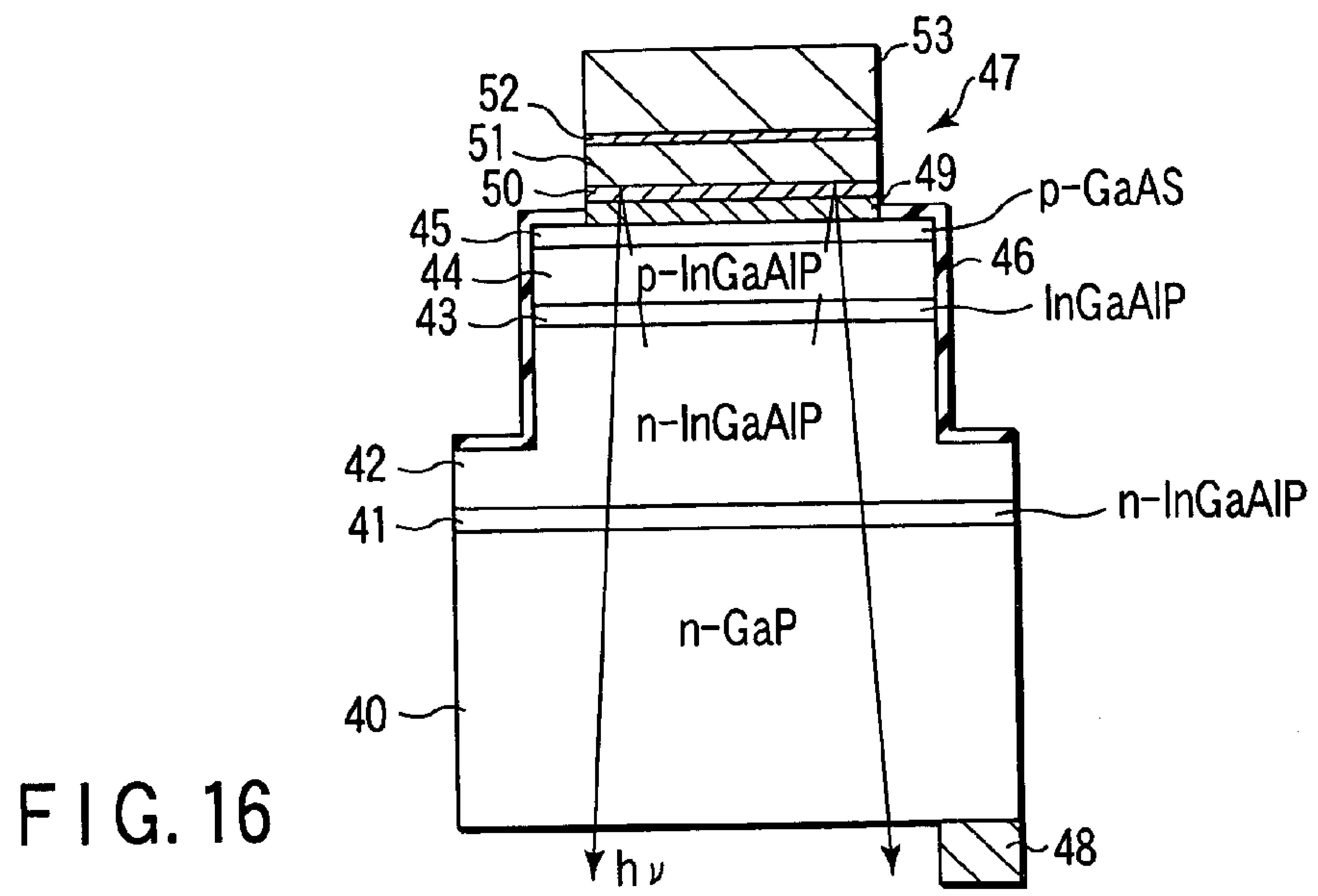


FIG. 16

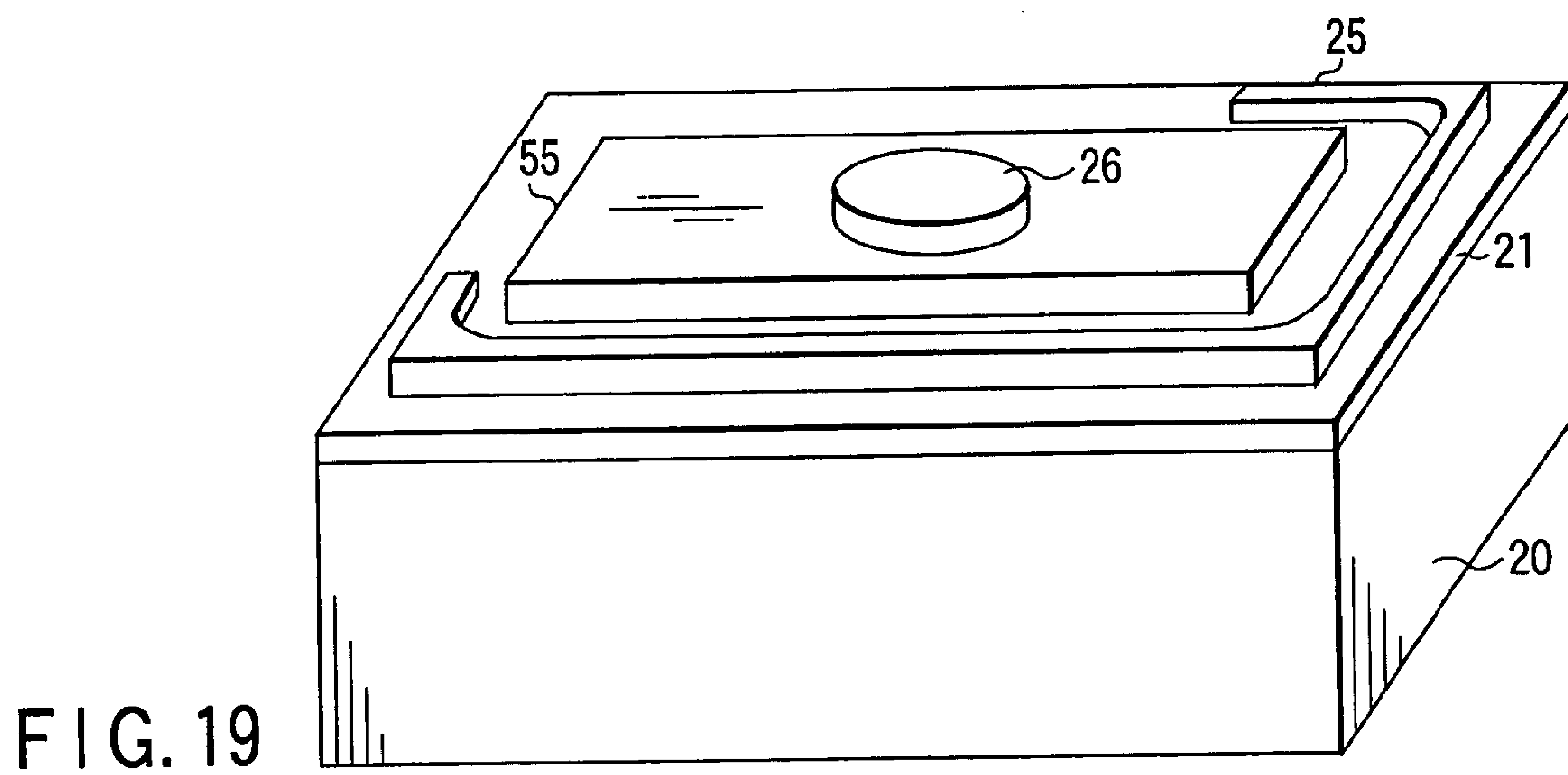


FIG. 19

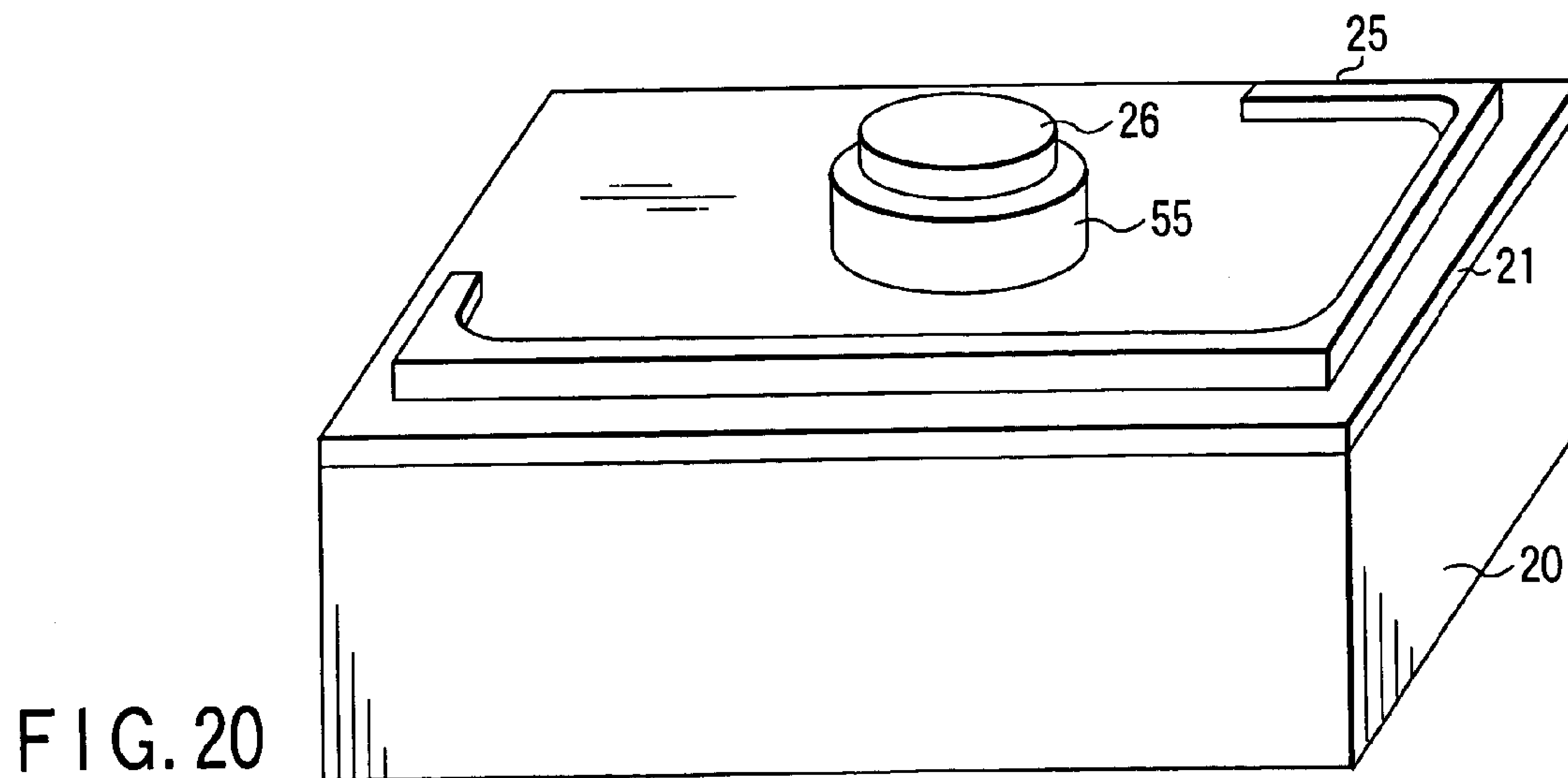


FIG. 20

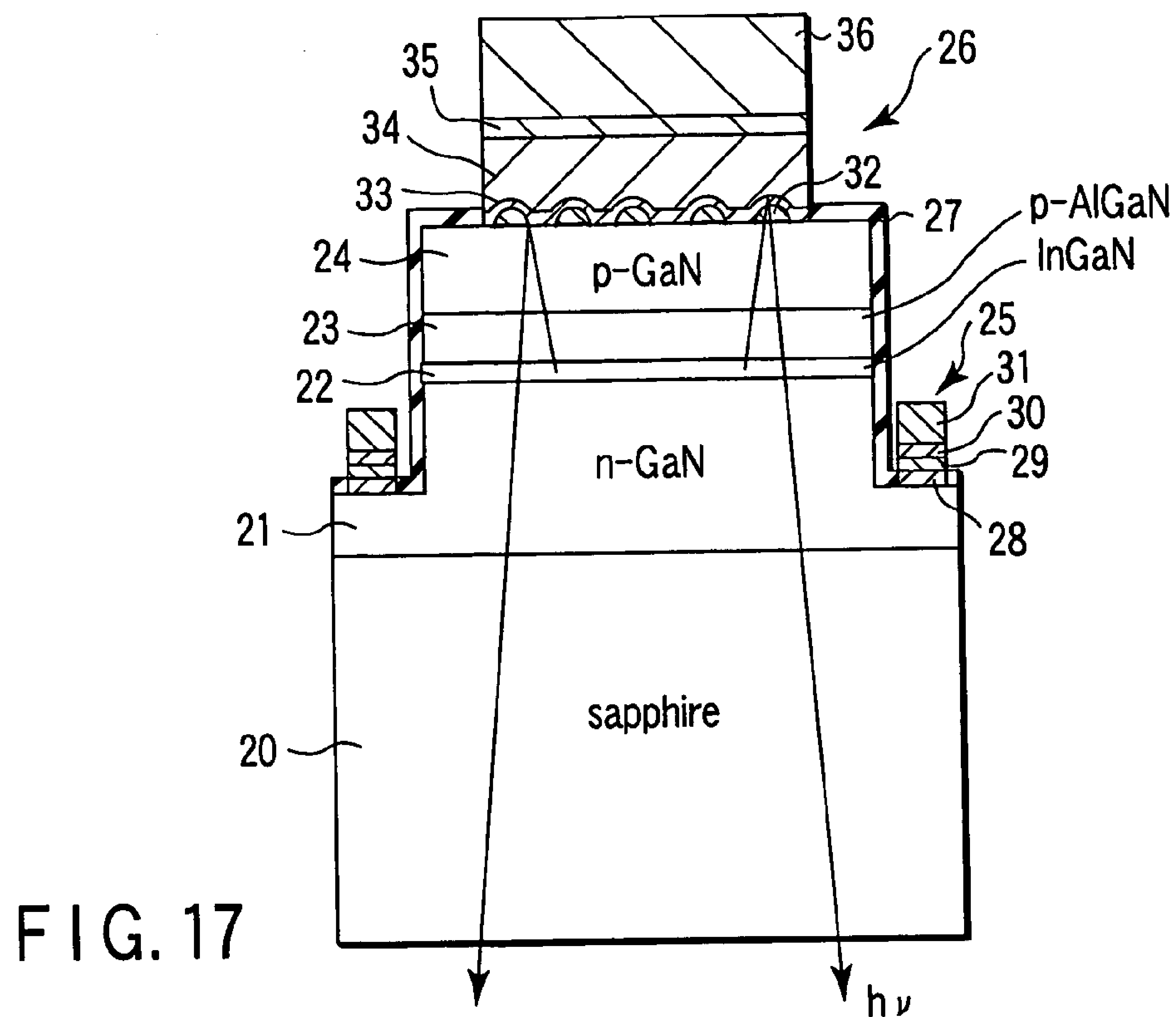


FIG. 17

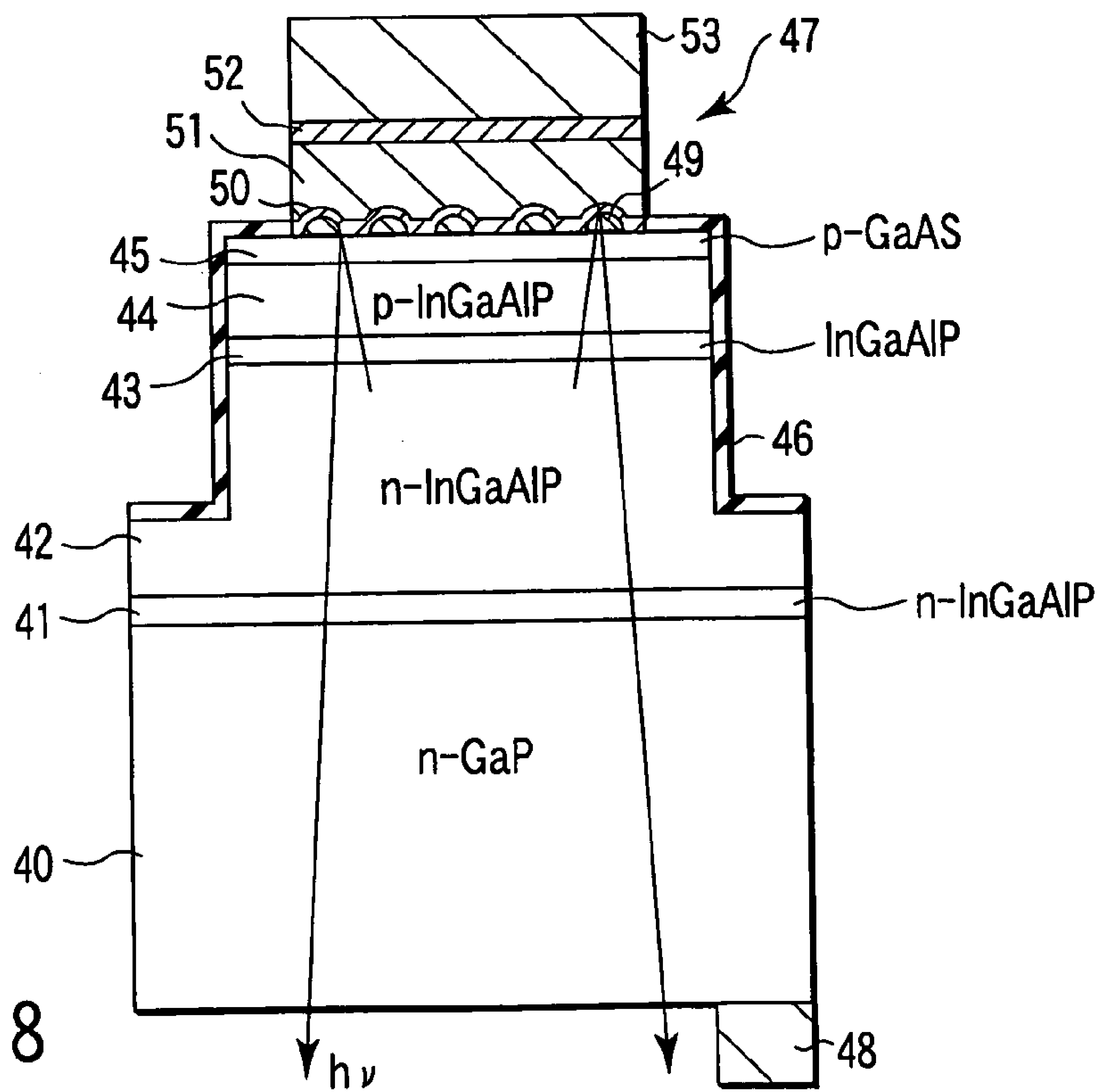


FIG. 18

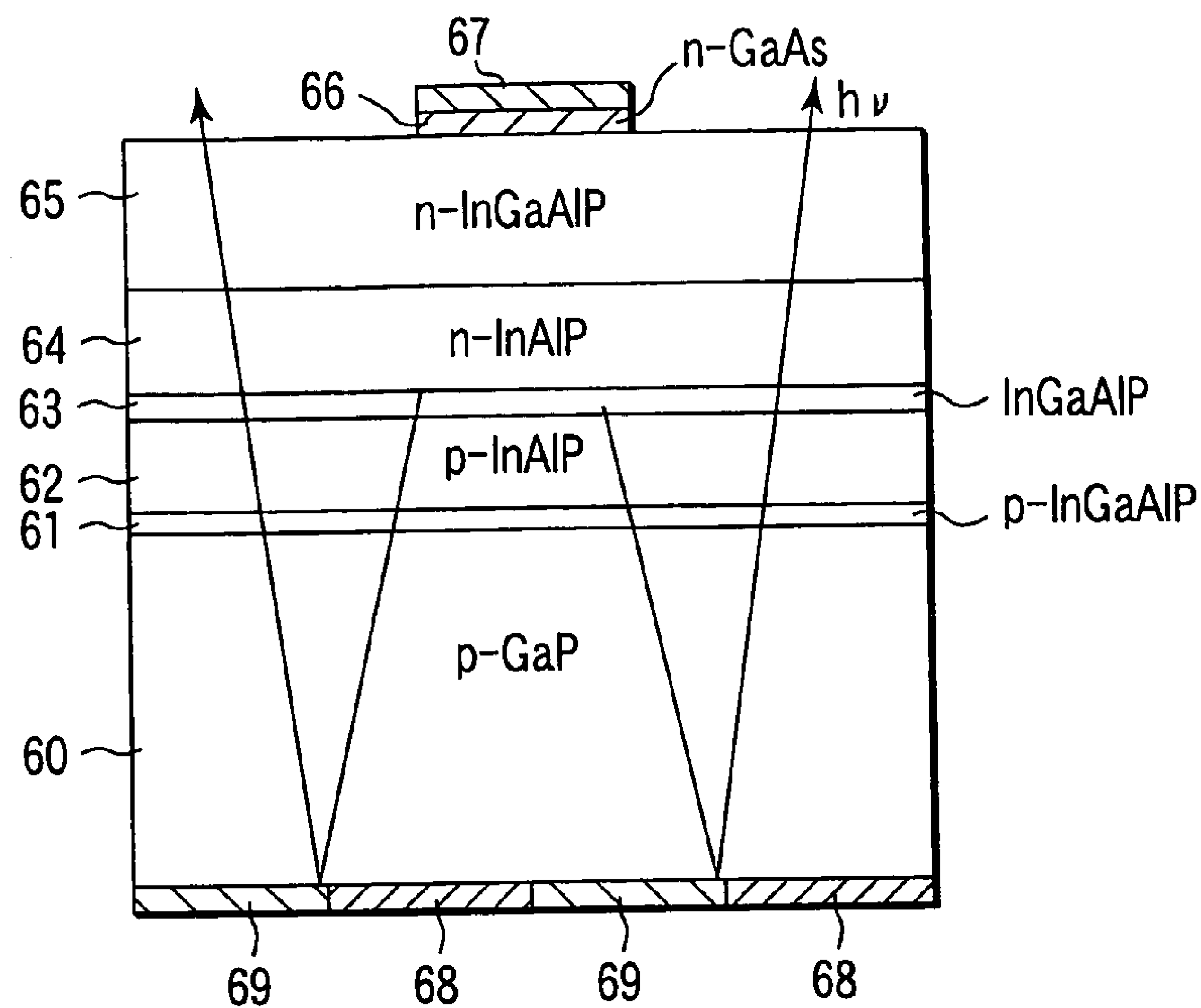


FIG. 21

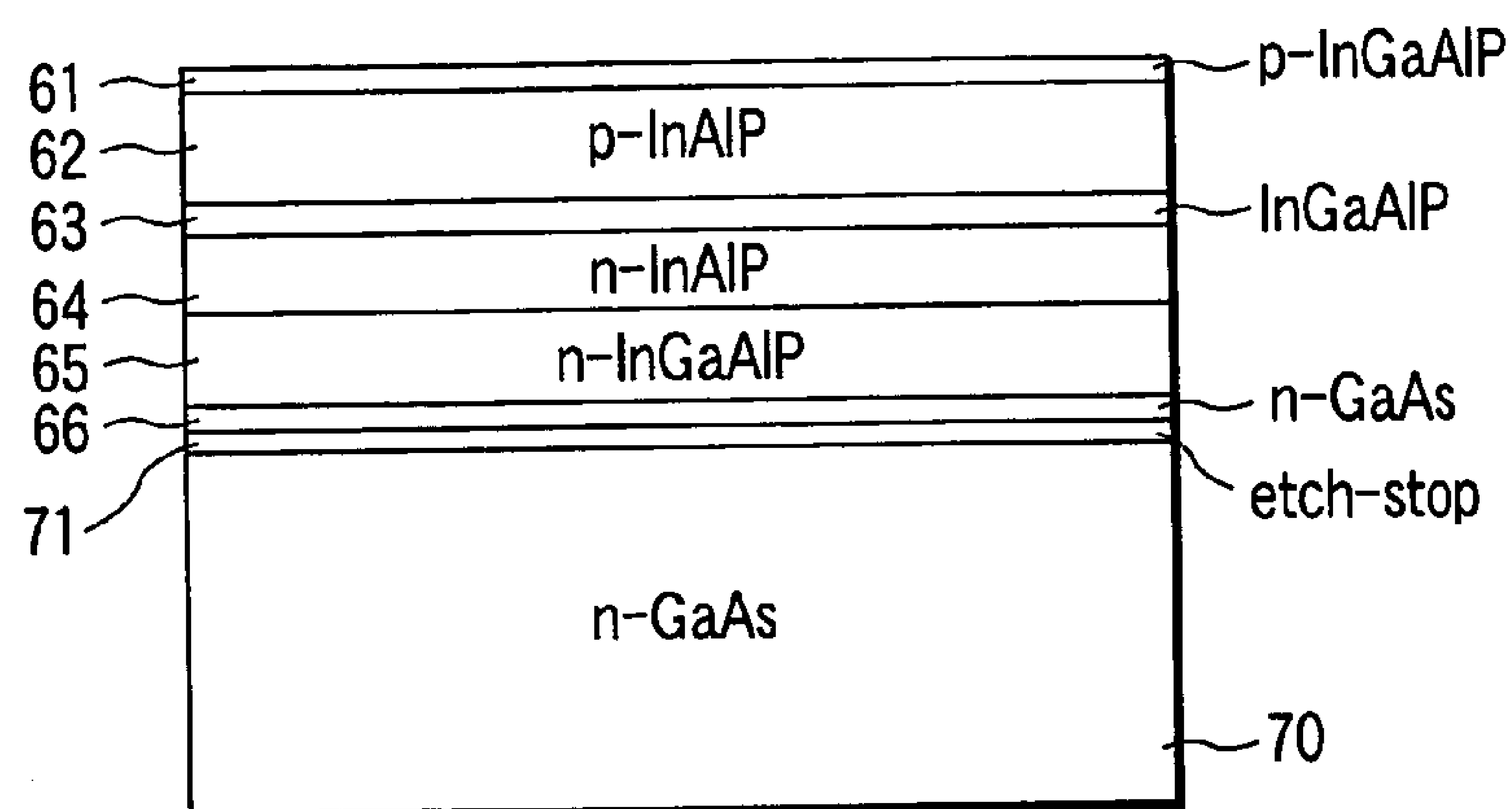


FIG. 22

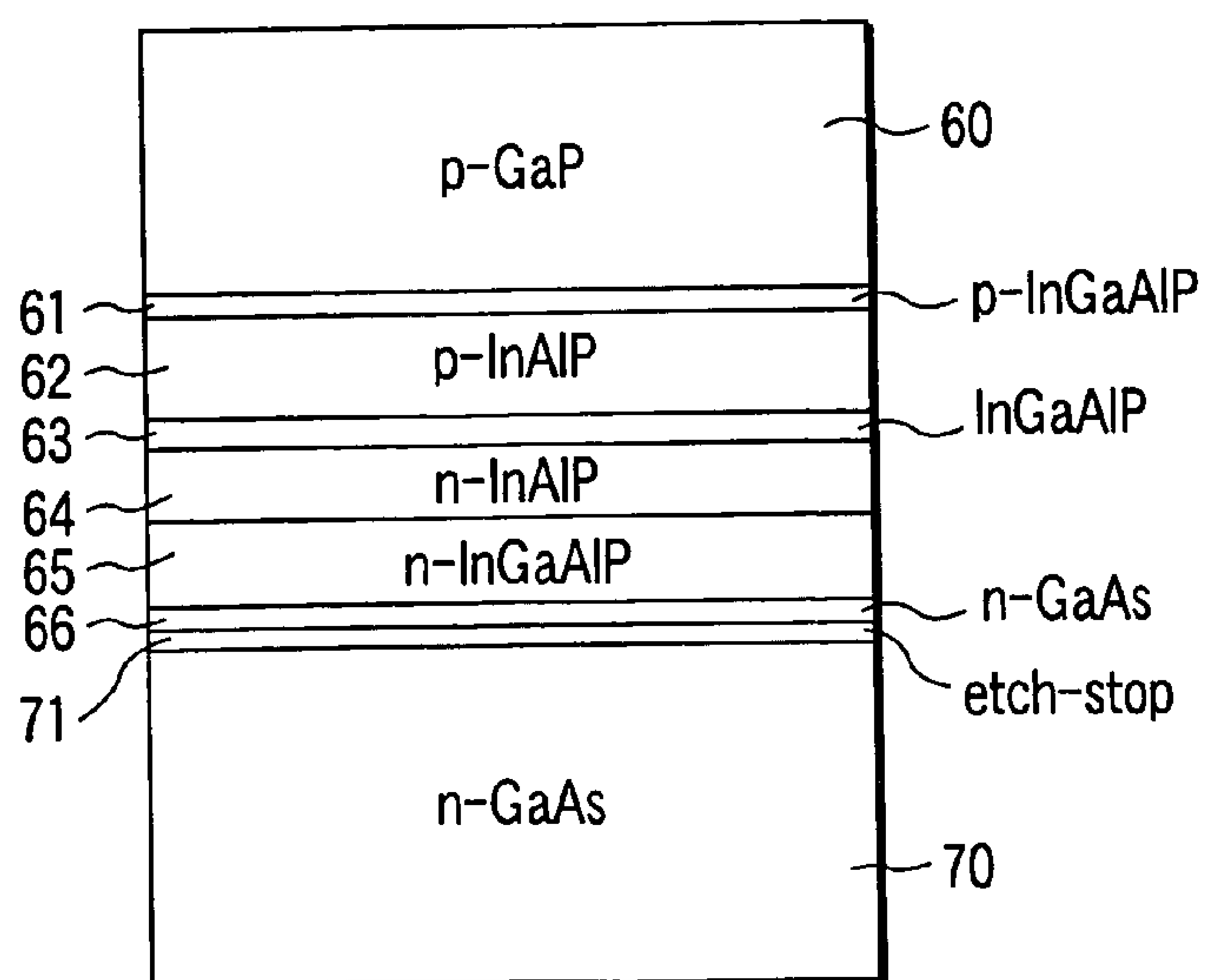


FIG. 23

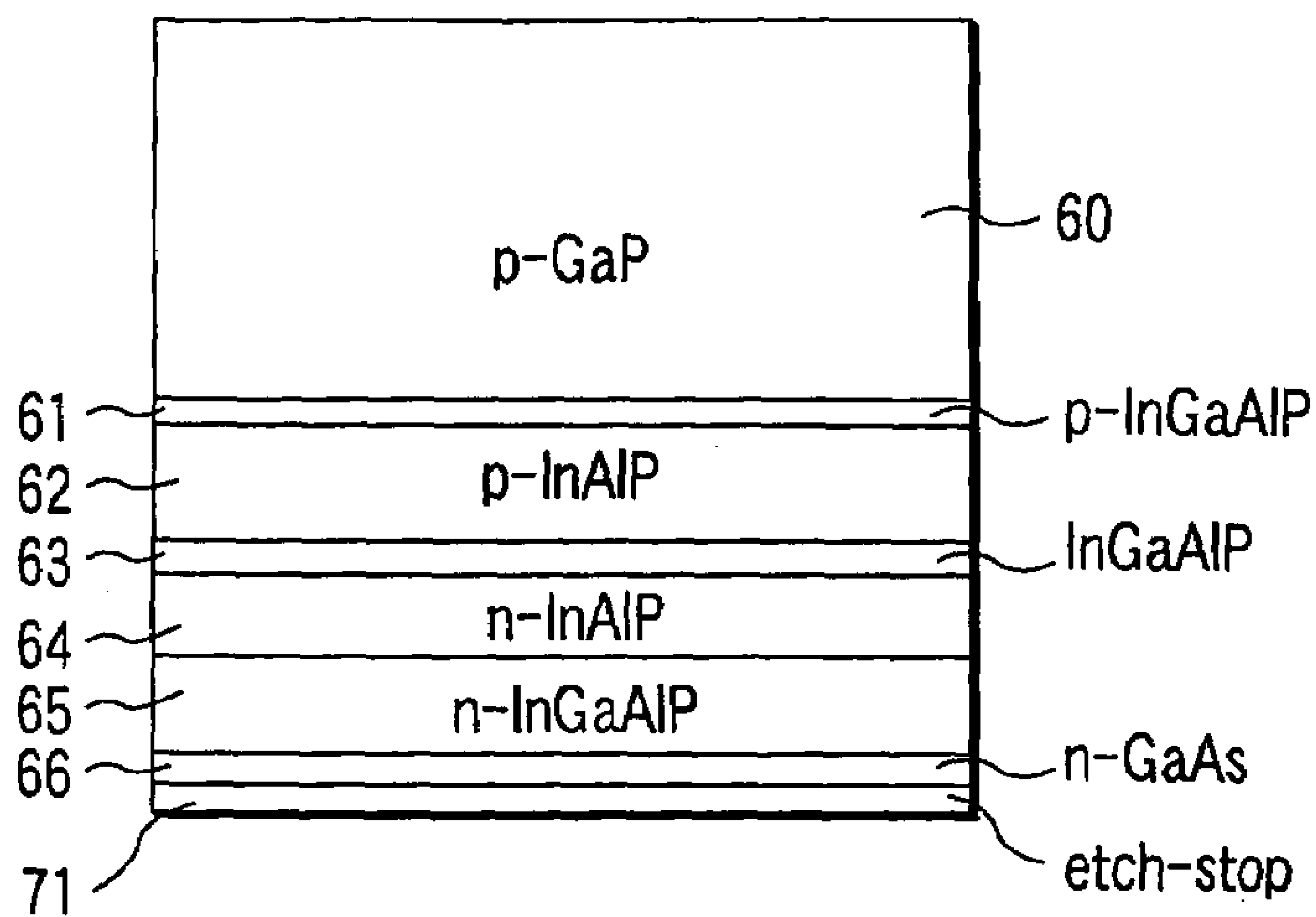


FIG. 24

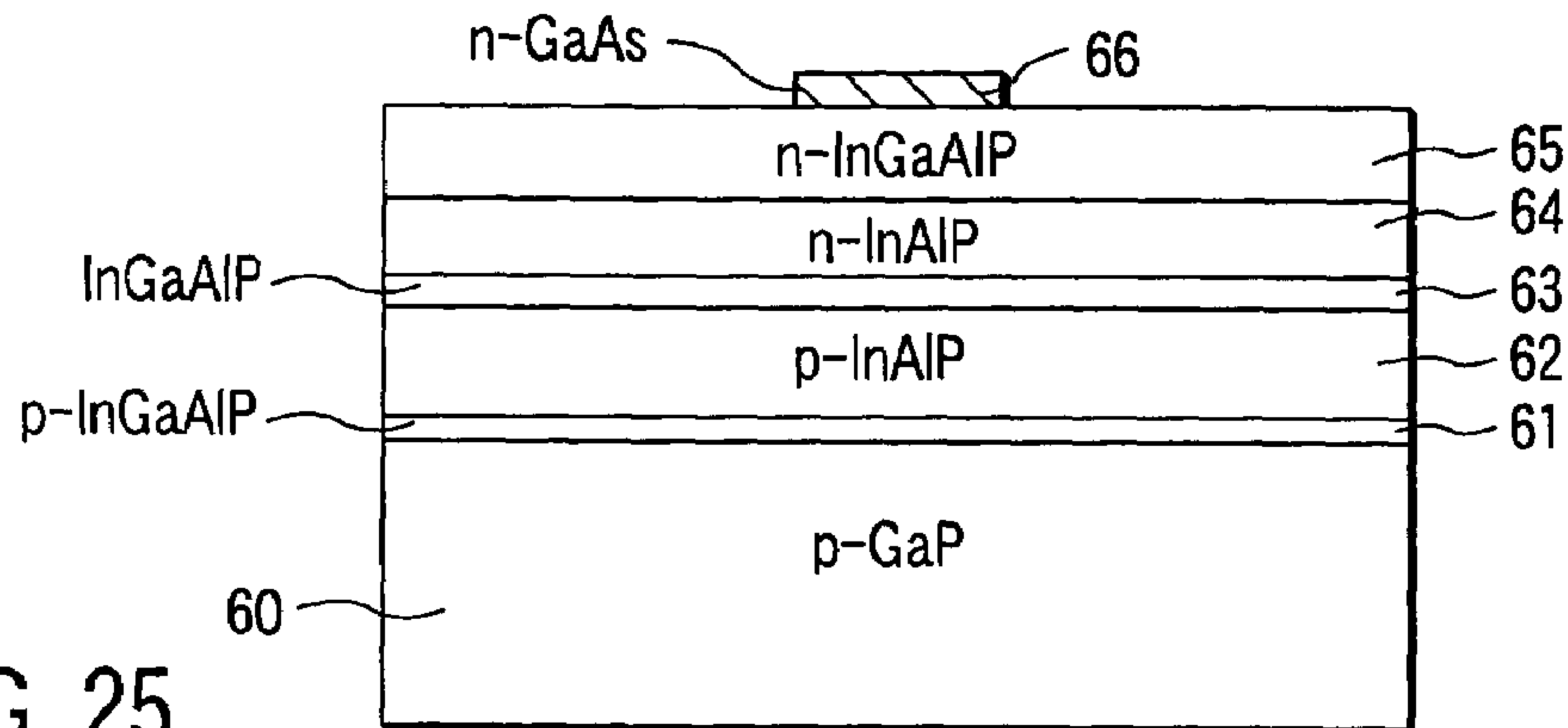


FIG. 25

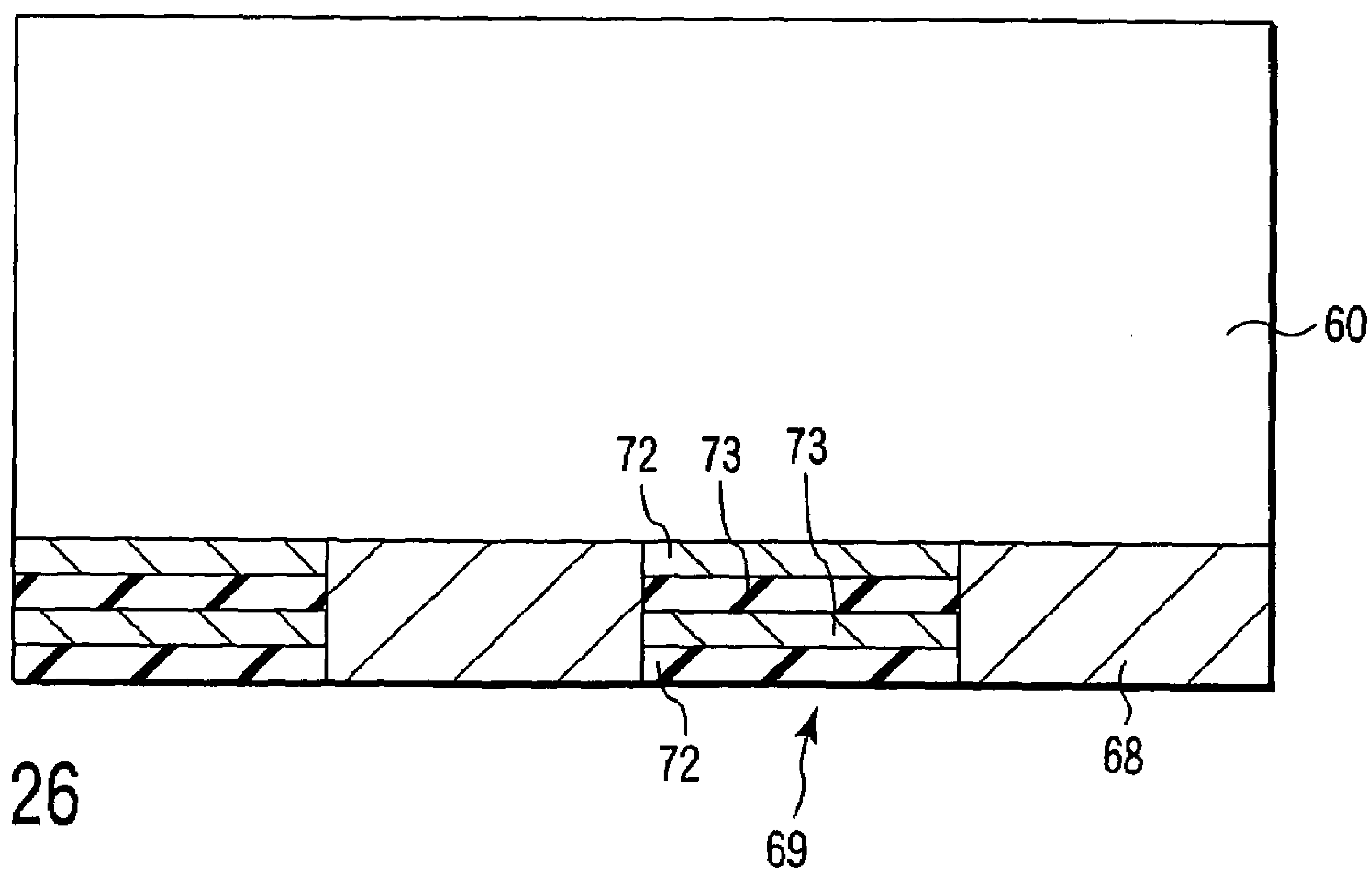


FIG. 26

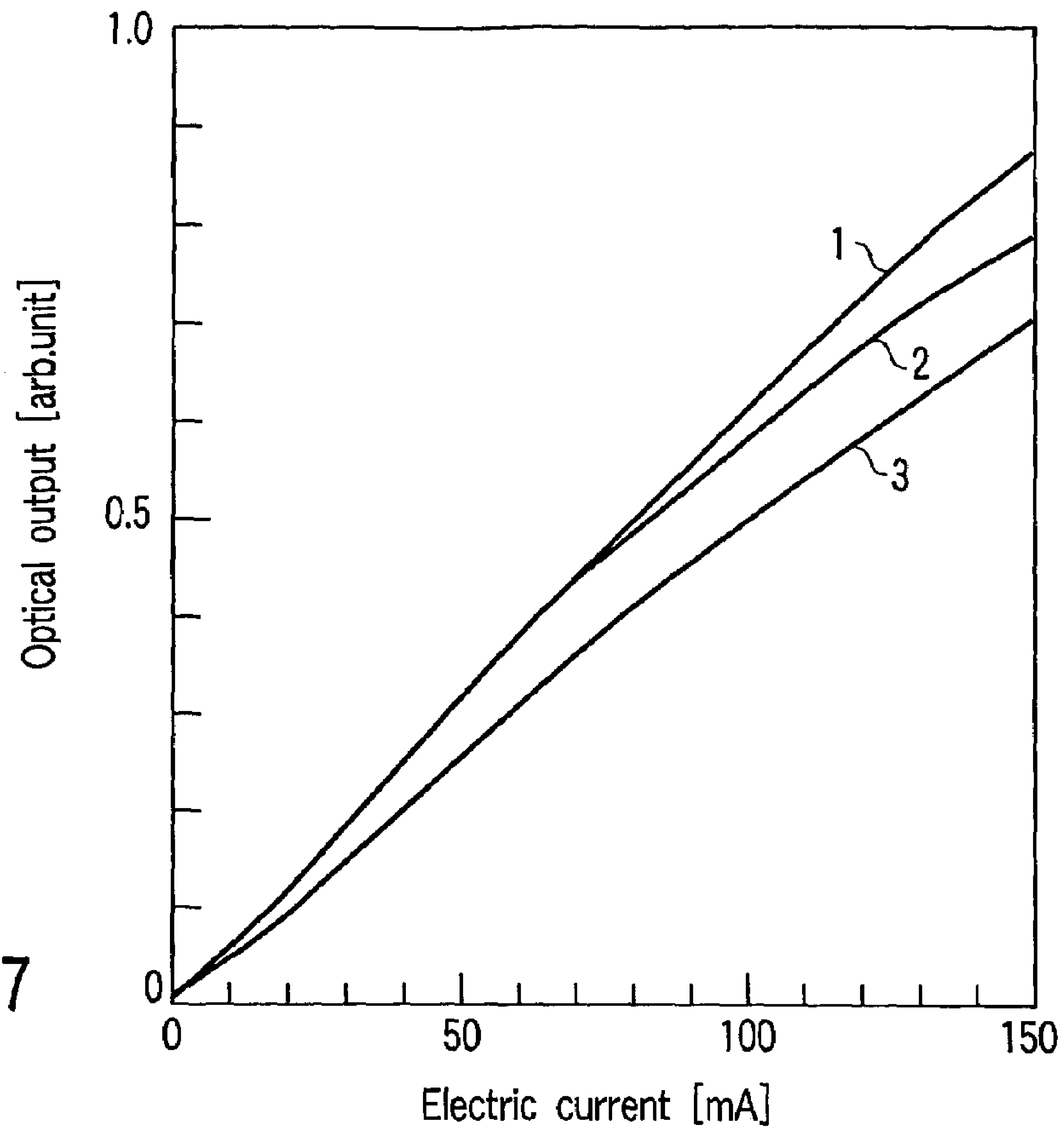


FIG. 27

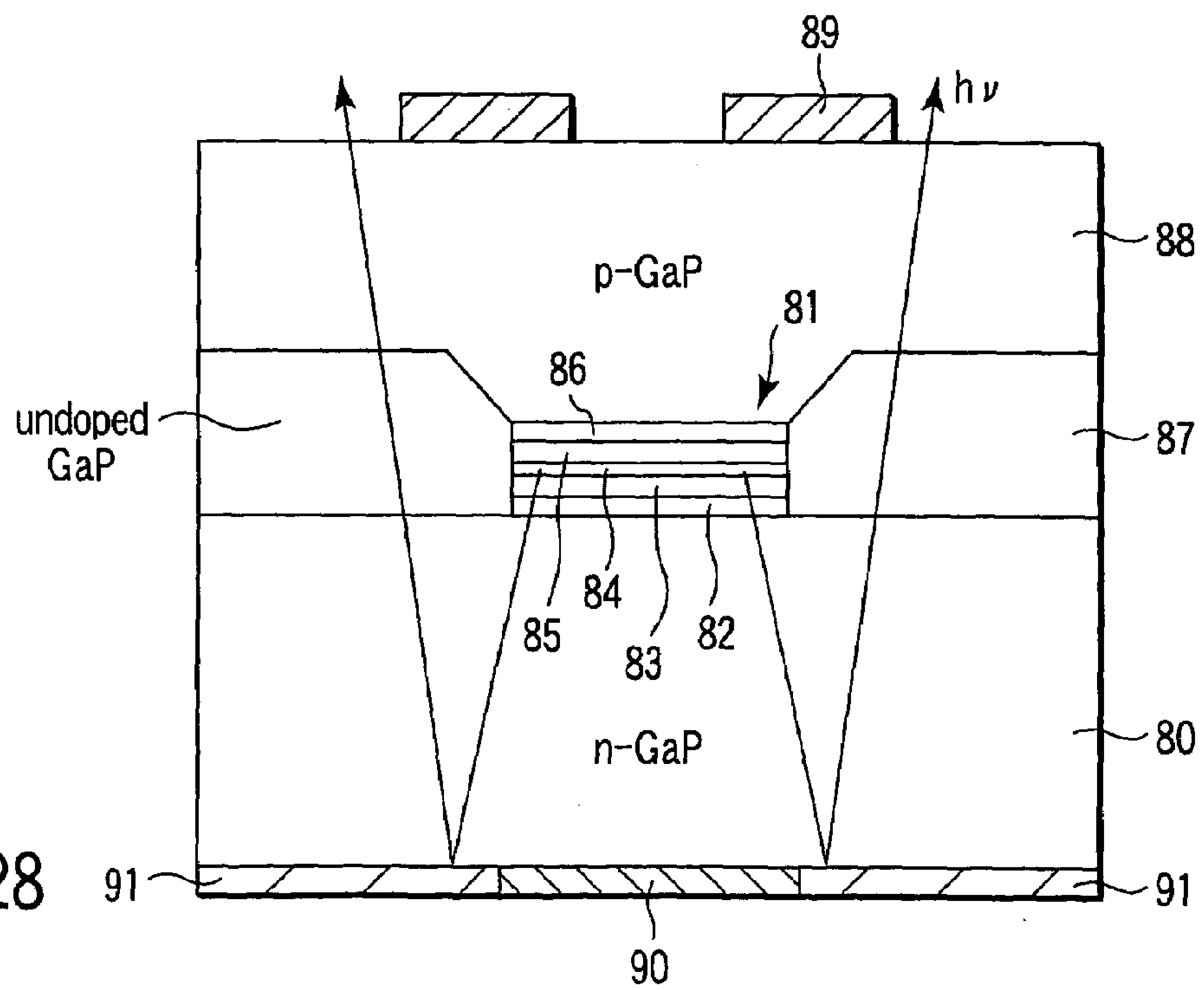


FIG. 28

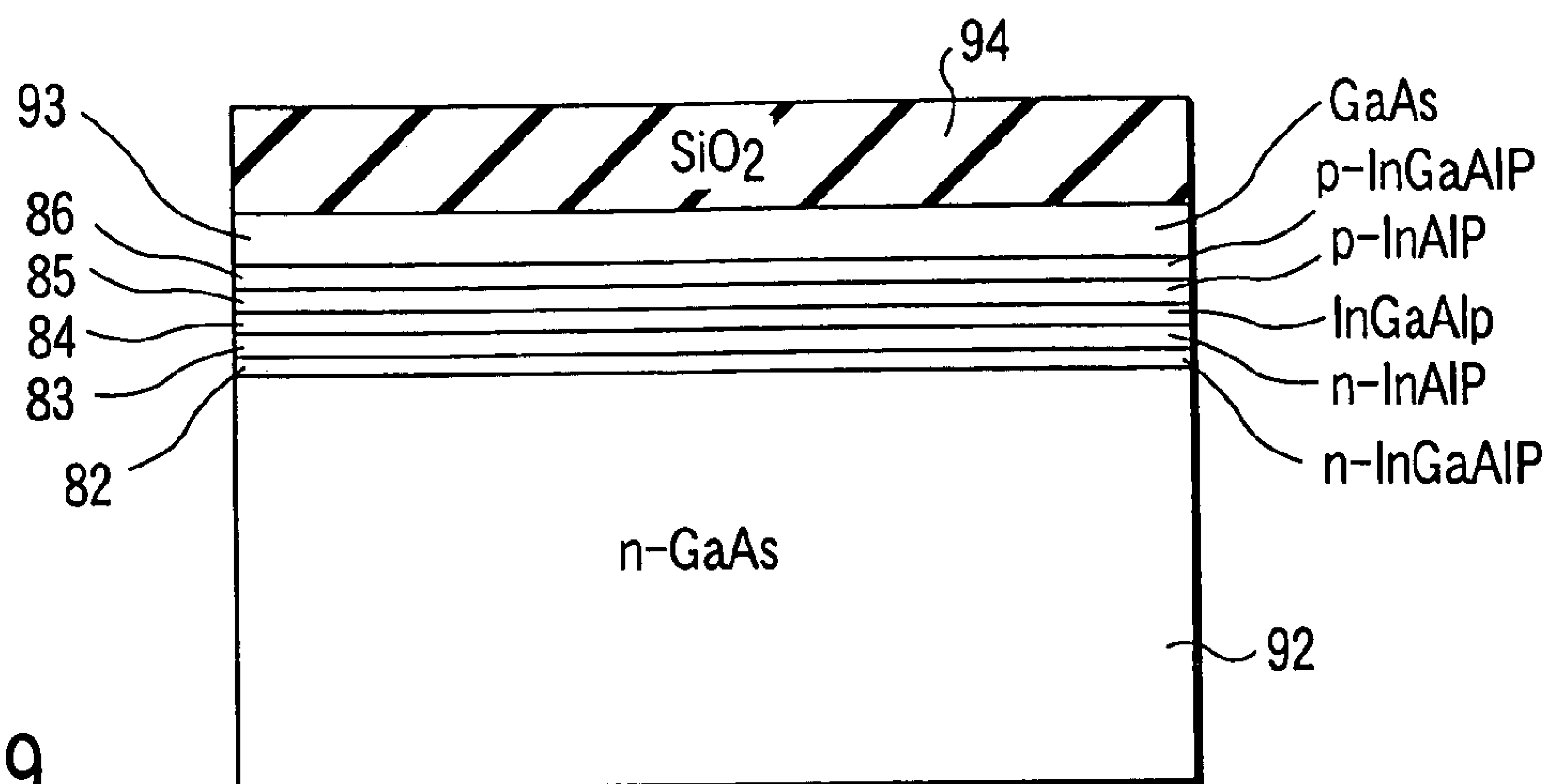


FIG. 29

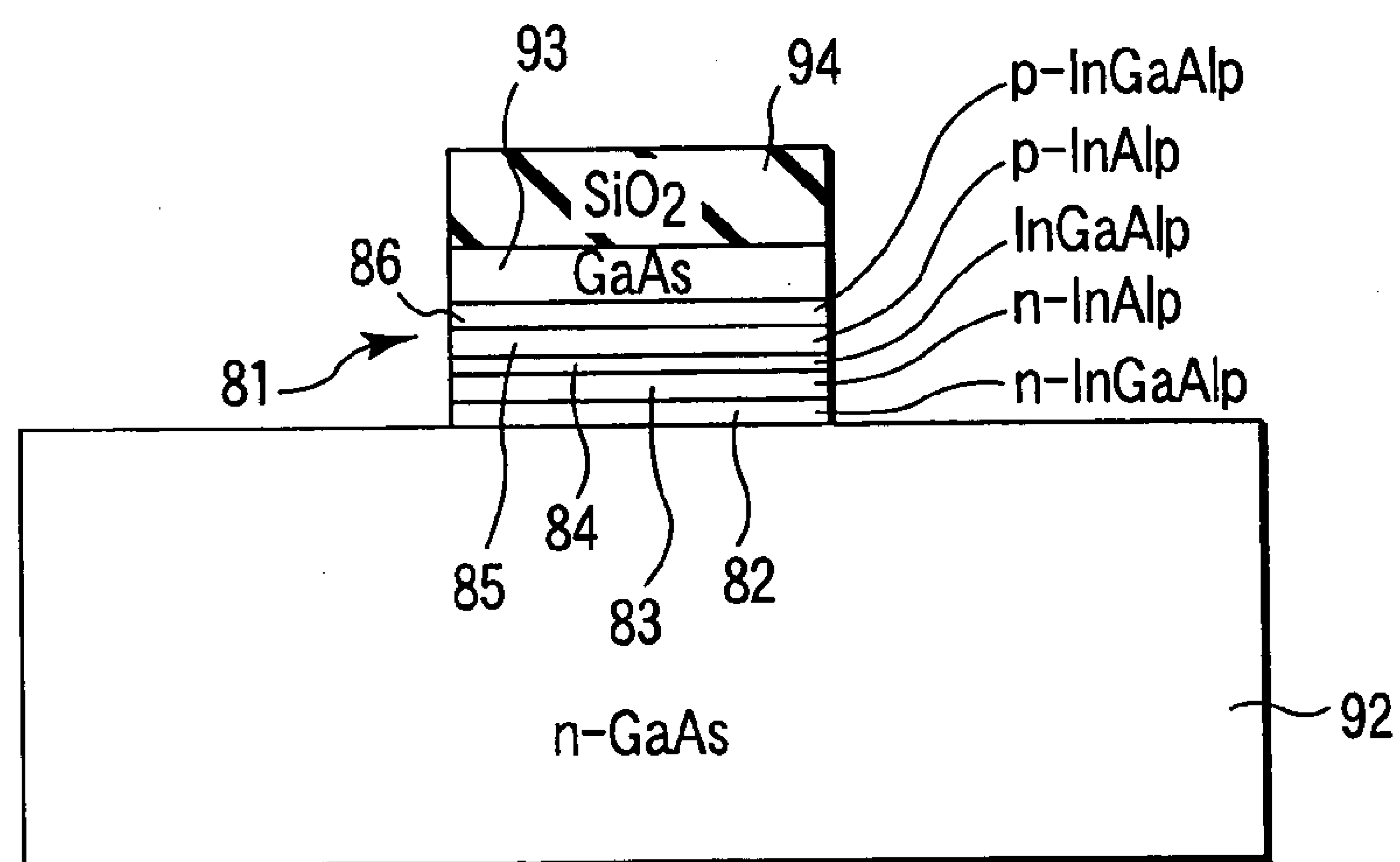


FIG. 30

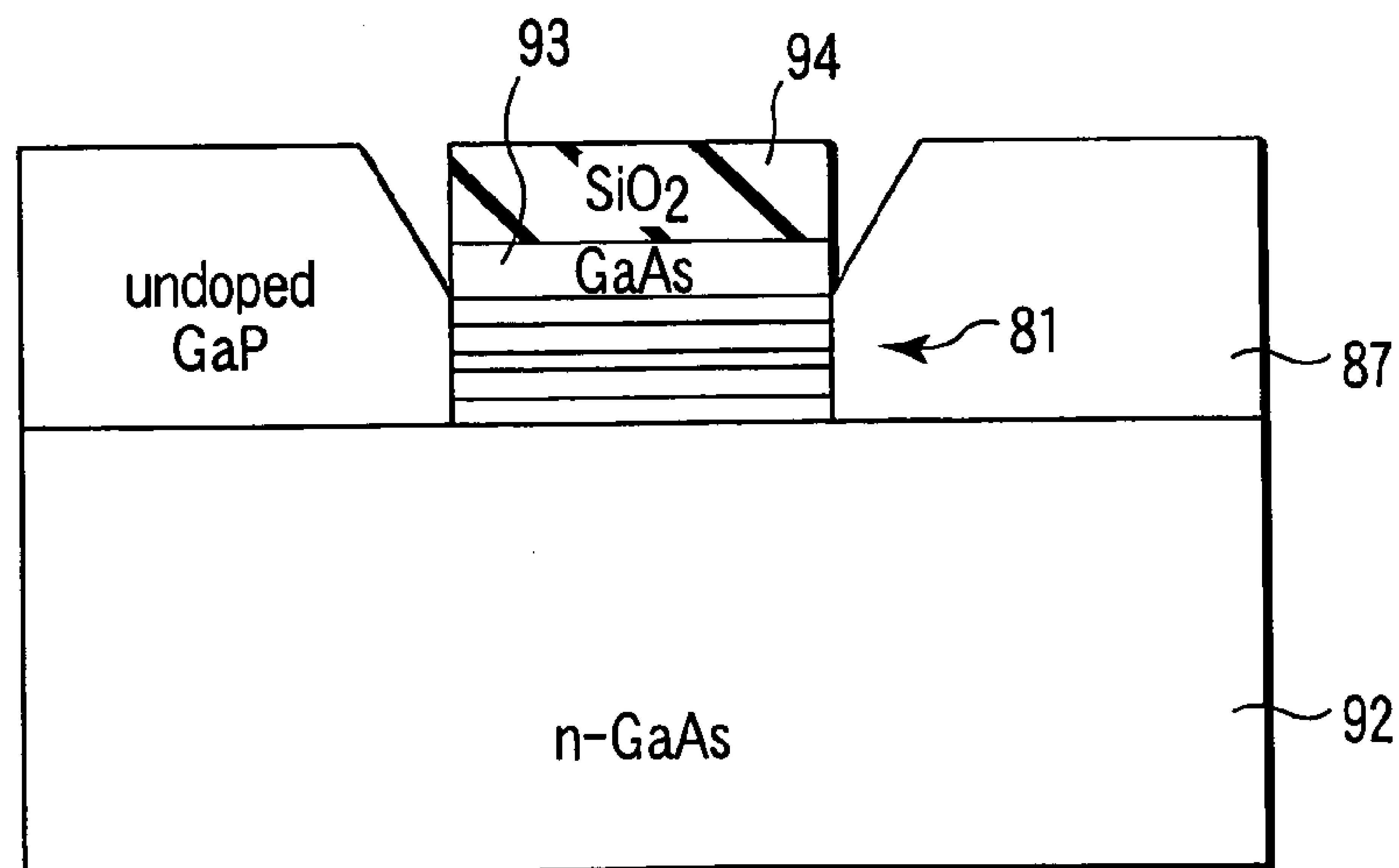


FIG. 31

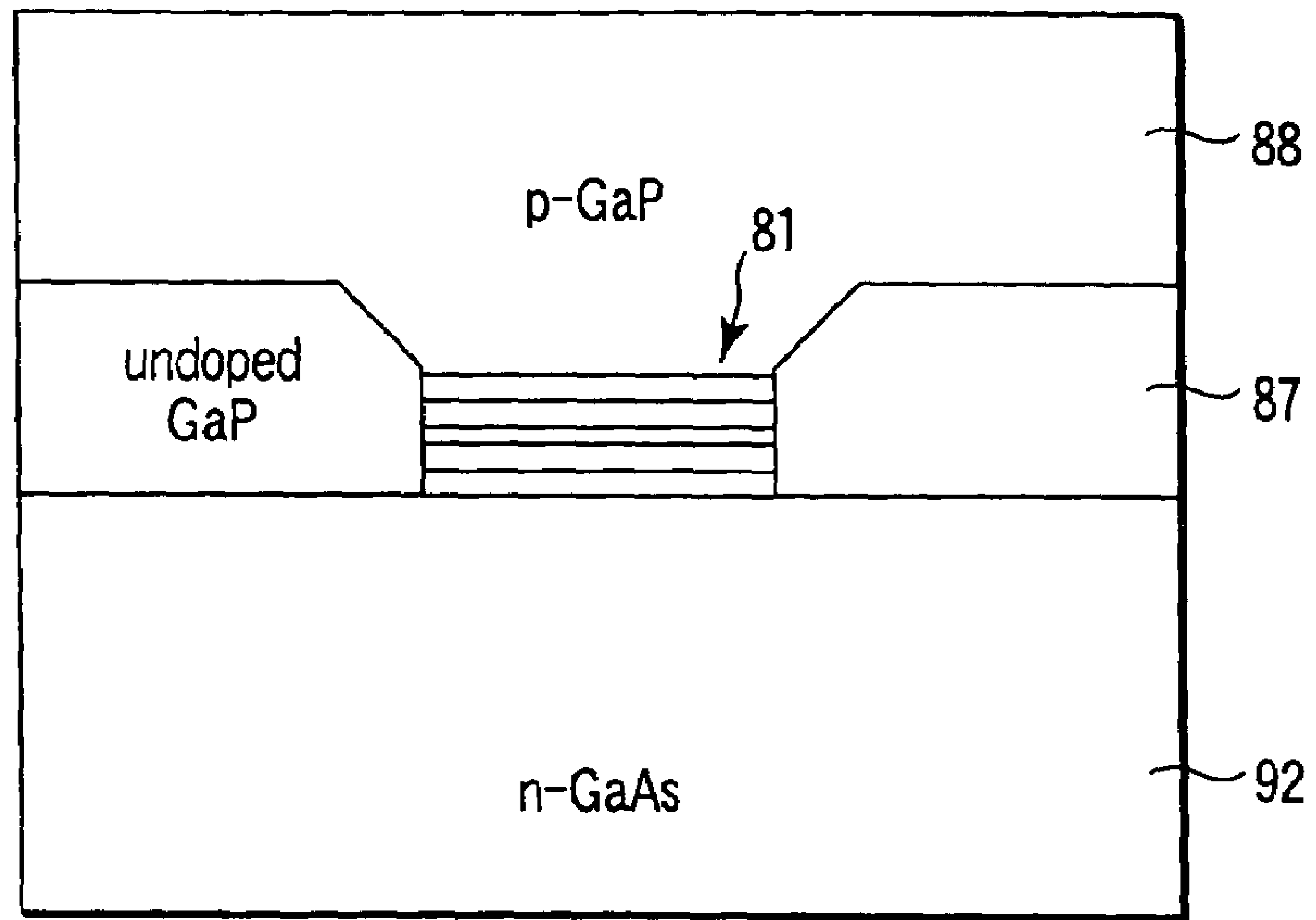


FIG. 32

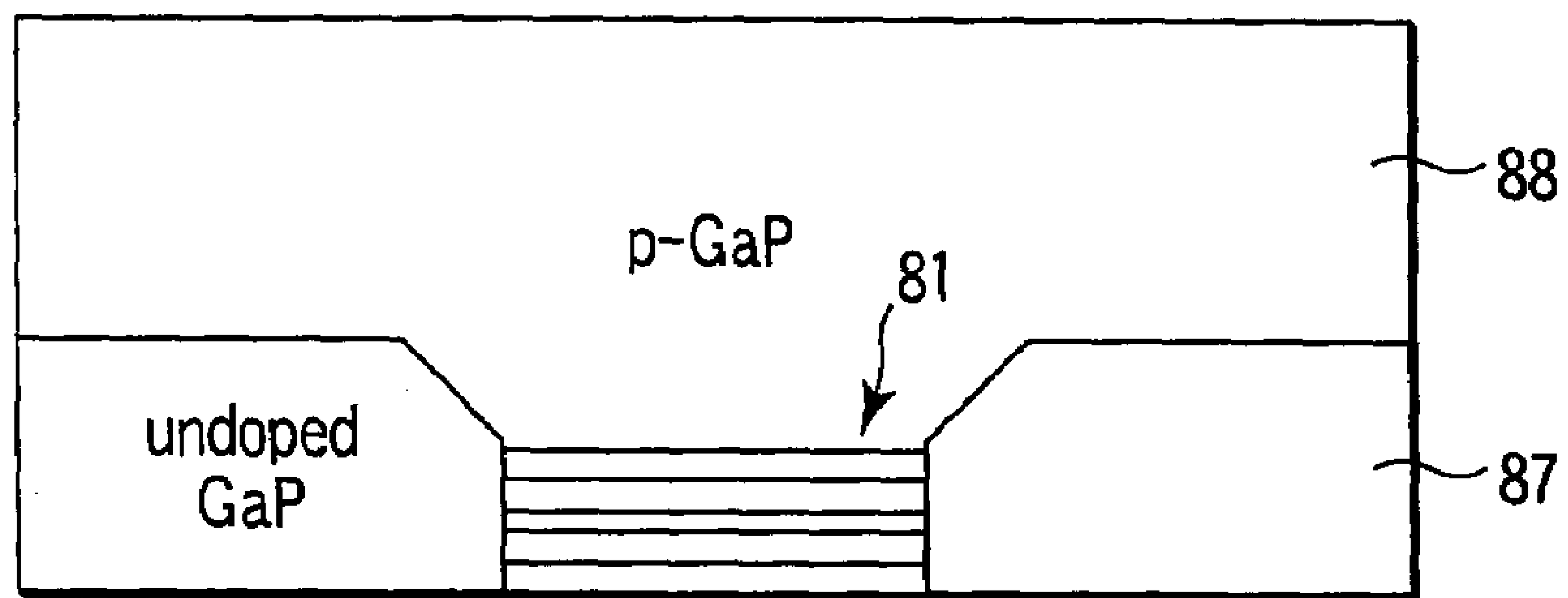


FIG. 33

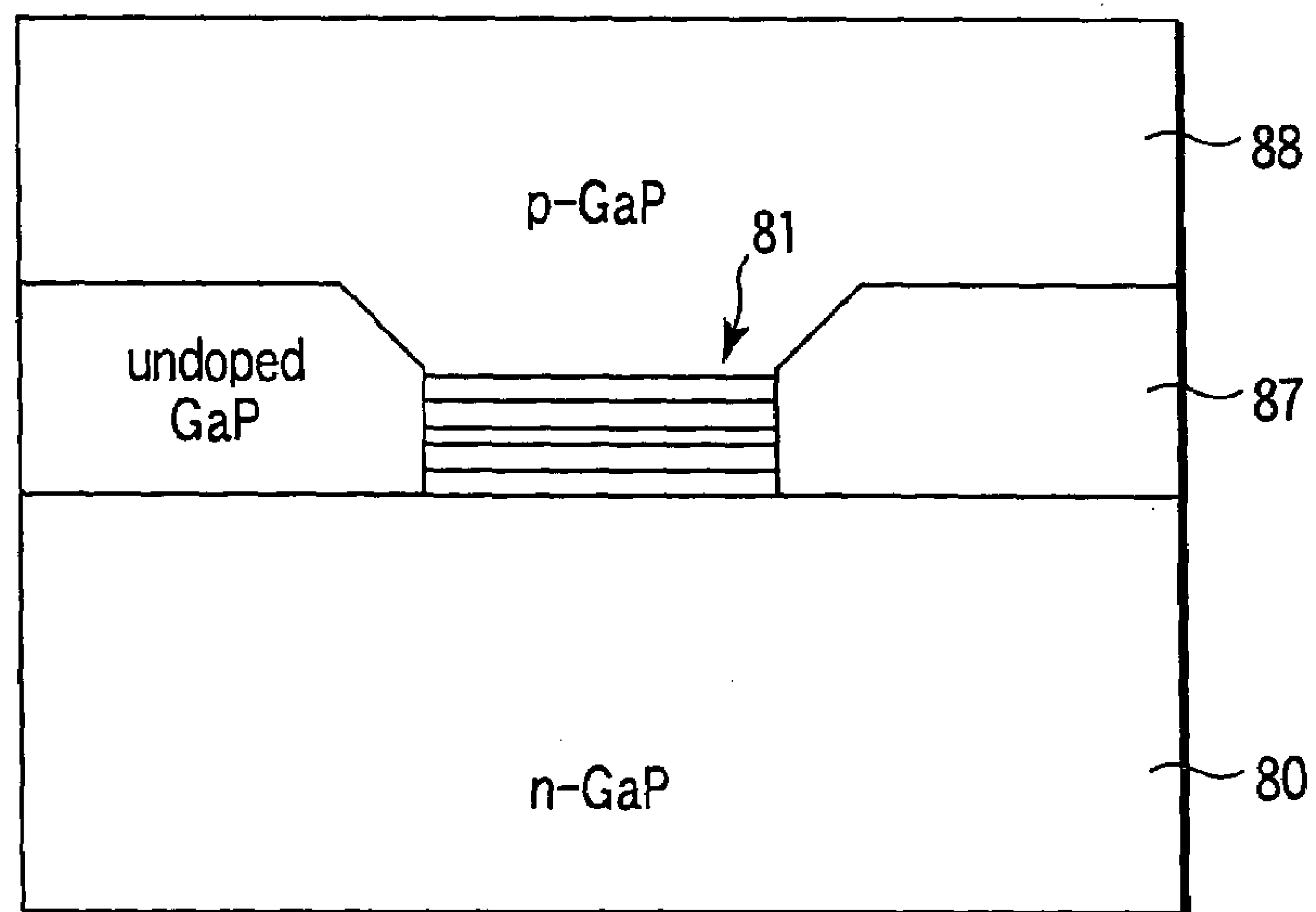


FIG. 34

LIGHT EMITTING ELEMENT, METHOD OF MANUFACTURING THE SAME, AND SEMICONDUCTOR DEVICE HAVING LIGHT EMITTING ELEMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a divisional of application Ser. No. 10/417,873, filed Apr. 17, 2003 now U.S. Pat. No. 6,825,502, which is a continuation of application Ser. No. 09/893,925, filed Jun. 27, 2001, now abandoned, which applications are hereby incorporated by reference in their entirety.

This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2000-200298, filed Jun. 30, 2000, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light emitting element and, more particularly, to the electrode structure of a light emitting element.

2. Description of the Related Art

The recent progress of light emitting elements is remarkable. In particular, small-sized, low-power-consumption, high-reliability light emitting diodes (LEDs) are developed and extensively used as display light sources.

Red, orange, yellow, and green LEDs currently put to practical use are made of group III-V compound semiconductors using As and P as group V elements, e.g., AlGaAs, GaAlP, GaP, and InGaAlP. On the other hand, green, blue, and ultraviolet LEDs are made of compound semiconductors such as GaN. In this way, LEDS having high emission intensity are realized.

When the luminance of these LEDs is increased, applications such as outdoor display devices and communication light sources are presumably greatly extended.

FIG. **1** shows the structure of a conventional violet LED.

A light emitting element **110** for emitting violet light is bonded on a lead frame **120** by silver paste **130**. The p- and n-electrodes of this light emitting element **110** are connected to the lead frame **120** by bonding wires **150**. The light emitting element **110** is covered with an epoxy resin **180**.

FIG. **2** shows the light emitting element shown in FIG. **1**.

On a sapphire (Al_2O_3) substrate **200**, an n-GaN layer **210** and a p-GaN layer **220** are formed. The n-GaN layer **210** has a recess. Since the p-GaN layer **220** is not present on this recess, the n-GaN layer **210** is exposed in this recess of the n-GaN layer **210**.

An n-side electrode **230** is formed on the recess of the n-GaN layer **210**. A transparent electrode **240** having properties of transmitting light is formed on the p-GaN layer **220**. In addition, a bonding electrode **250** for wire bonding is formed on the p-GaN layer **220**.

When a voltage is applied between the two lead frames **120** in the LED shown in FIGS. **1** and **2**, an electric current is injected into the p-GaN layer **220** from the bonding electrode. **250** and the transparent electrode **240**. This electric current flows from the p-GaN layer **220** to the n-GaN layer **210**.

In the boundary (p-n junction) between the p-GaN layer **220** and the n-GaN layer **210**, light having energy hv (h: Planck's constant, $\nu=c/\lambda$, c: velocity of light, λ: wavelength) is generated when the electric current flows. This light is emitted upward from the transparent electrode **240**.

In the transparent electrode **240**, however, the light transmittance and the conductivity have a relationship of trade-off.

That is, to increase the light transmittance, the thickness of the electrode need only be decreased. However, if the electrode thickness is decreased, the conductivity lowers. When the conductivity lowers, no electric current can be supplied to the whole p-n junction any longer, and this decreases the light generation efficiency. Also, to increase the conductivity, the thickness of the electrode need only be increased. However, if the electrode thickness is increased, the light transmittance lowers. When the light transmittance lowers, light generated in the p-n junction cannot be efficiently extracted to the outside of the chip.

As a technology by which this problem is solved, a technology of emitting light toward the sapphire substrate **200** is known.

FIG. **3** shows a light emitting element using this technology.

Since this light emitting element is bonded on a lead frame by flip chip bonding, an LED having this light emitting element is called a flip chip type LED.

A high-reflectance electrode **260** is formed on p-GaN **220**. Of light generated in the p-n junction, light traveling to a sapphire substrate **200** is directly emitted to the outside of the chip. Of light generated in the p-n junction, light heading to the electrode **260** is reflected by this electrode **260**. The reflected light travels to the sapphire substrate **200** and is emitted to the outside of the chip.

The sapphire substrate **200** will be described below.

When InGaN is used as an active layer, an LED currently put to practical use emits light within the range of blue to green. The bandgap of the sapphire substrate **200** is approximately 3.39 eV (wavelength $\lambda\approx365$ nm) at room temperature (300K). That is, the sapphire substrate **200** has properties of transmitting light within the range of blue to green (the wavelength λ is approximately 400 to 550 nm).

A flip chip type LED is very effective as a technology of extracting light to the outside of the chip with high efficiency, but also has a problem.

That is, it is generally difficult to form an ohmic contact with the p-GaN **220** when the high-reflectance electrode **260** is used. This ohmic contact is an essential technology to reduce the contact resistance between the electrode **260** and the p-GaN **220** and thereby improve the performance of the element.

Conventionally, therefore, the electrode **260** is given a two-layered structure including an ohmic layer for forming an ohmic contact and a high-reflection layer having high reflectance. The ohmic layer improves the performance and the high-reflection layer increases the light emission efficiency at the same time.

Unfortunately, the ohmic layer obtains an ohmic contact by interdiffusion of metal atoms between this ohmic layer and the p-GaN **220**, so these metal atoms naturally diffuse from the ohmic layer to the high-reflection layer. Since this diffusion lowers the performance and reliability of the light emitting element, it must be eliminated.

FIG. **4** shows an LED made of group III-V compound semiconductors having As and P as group V elements.

This LED emits light within the range of red to green.

On an n-GaAs substrate **300**, an n-GaAs buffer layer **310** and an n-InGaAlP cladding layer **320** are formed. On this

n-InGaAlP cladding layer **320**, an InGaAlP active layer **330**, a p-InGaAlP cladding layer **340**, and a p-AlGaAs current diffusing layer **350** are formed.

On the p-AlGaAs current diffusing layer **350**, a p-GaAs contact layer **360** and a p-side electrode **370** are formed. An n-side electrode **380** is formed on the back side of the n-GaAs substrate **300**.

In a light emitting element made of group III-V compound semiconductors (e.g., GaAs, AlGaAS, and InGaAlP) having As and P as group V elements, a sufficiently thick current diffusing layer (the AlGaAs current diffusing layer **350**) is formed on a p-semiconductor layer without forming any transparent electrode on a p-semiconductor layer (the InGaAlP cladding layer **340**). This sufficiently thick current diffusing layer has a function of evenly injecting an electric current into the entire InGaAlP active layer **330**. Since the AlGaAs current diffusing layer **350** increases the light generation efficiency in the vicinity of the active layer, satisfactory optical power can be assured.

In the light emitting element shown in FIG. **4**, an electric current given to the p-side electrode **370** is injected into the InGaAlP active layer **330** via the p-AlGaAs current diffusing layer **350**. Light generated near the InGaAlP active layer **330** is emitted upward from the p-AlGaAs current diffusing layer **350** except for a region where the p-side electrode **370** exists.

The film thickness, however, of the current diffusing layer **350** must be increased to well diffuse the electric current for the reason explained below. That is, if the film thickness is small, the electric current is not diffused but injected only into the active layer **330** immediately below the p-side electrode **370**. Consequently, most of the light generated near the active layer **330** is interrupted by the p-side electrode **370**.

In the fabrication of an LED and an LD (Laser Diode), MO-CVD (Metal Organic-Chemical Vapor Deposition) or MBE (Molecular Beam Epitaxy) is often used as a crystal growth method. This is so because these methods can well control the film thickness in the formation of a thin film and thereby can form a high-quality film.

Unfortunately, these methods have the problem that they are inappropriate to form sufficiently thick films. That is, when MO-CVD or MBE is used, a very long time is required to form the sufficiently thick current diffusing layer **350** used in the light emitting element shown in FIG. **4**. This worsens the productivity.

Additionally, in the light emitting element shown in FIG. **4**, the light generated in the InGaAlP active layer **330** is absorbed by the n-GaAs substrate **300**. This lowers the light extraction efficiency of the light emitting element shown in FIG. **4**.

As a method of solving this problem of light absorption by the GaAs substrate **300**, it is possible to form a flip chip type LED described earlier. However, the GaAs substrate **300** is opaque. Accordingly, a device from which this GaAs substrate **300** is removed is prepared, and a transparent substrate which transmits light is bonded to this device.

FIG. **5** shows a light emitting element using this technology.

On a p-GaP substrate **400**, a p-InGaAlP adhesive layer **410** and a p-InGaAlP cladding layer **420** are formed. An InGaAlP active layer **430** is formed on the p-InGaAlP cladding layer **420**. On this InGaAlP active layer **430**, an n-InGaAlP cladding layer **440** and an n-AlGaAs window layer **450** are formed.

In addition, an electrode **460** having high reflectance and an n-side electrode **470** are formed on the AlGaAs window layer **450**. A p-side electrode **480** is formed on the back side of the p-GaP substrate **400**.

Note that the GaP substrate **400** has a bandgap of 2.26 eV ($\lambda \approx 548$ nm) at room temperature and is transparent to red light.

With this arrangement, of light generated in the InGaAlP active layer **430**, light traveling to the p-GaP substrate **400** is directly emitted to the outside of the chip. Also, of light generated in the InGaAlP active layer **430**, light heading to the electrode **460** is reflected by this electrode **460** having high reflectance. This reflected light travels to the p-GaP substrate **400** and is emitted to the outside of the chip.

In the electrode **460**, however, it is difficult to achieve an ohmic contact and high reflectance at the same time by the use of a single material. Therefore, this electrode **460** is given a two-layered structure including an ohmic layer and high-reflection layer. In this case, as described previously, the interdiffusion of metals between the ohmic layer and the high-reflection layer is a problem.

FIG. **6** shows a light emitting element using the technology of bonding a GaP substrate to a device from which a GaAs substrate is removed.

In this technology, light is reflected by the bonding surface between a GaP substrate **400** and a p-side substrate **480** and extracted upward from an AlGaAs window layer **450**.

Compared to the light emitting element shown in FIG. **5**, this light emitting element shown in FIG. **6** is characterized by having no high-reflectance electrode on the n-AlGaAs window layer **450**. In this structure, however, an alloy layer produced in the boundary between the p-GaP substrate **400** and the p-side electrode **480** scatters and absorbs light. This makes effective extraction of light to the outside of the chip difficult.

As described above, light is extracted from the conventional light emitting elements by the two methods: extraction from a light emitting layer, and extraction from a substrate.

When, however, a transparent electrode for diffusing an electric current is formed on the entire surface of a light emitting layer and light is extracted from this light emitting layer, the trade-off between the light transmittance and the conductivity is a problem. That is, if the thickness of the transparent electrode is decreased to increase the light transmittance, the conductivity lowers; if the thickness of the transparent electrode is increased to increase the conductivity, the light transmittance lowers.

In a structure in which an n-side electrode is formed on a portion of a light emitting layer and a thick current diffusing layer is formed below this n-side electrode, if light is to be extracted from the light emitting layer by reflecting it by a p-side electrode formed on the back side of a GaP substrate, this light is scattered and absorbed by the bonding surface between the GaP substrate and the p-side electrode. This worsens the light extraction efficiency.

Also, in a structure in which an n-side electrode is formed on a portion of a light emitting layer and a thick current diffusing layer is formed below this n-side electrode, if light is to be extracted from the substrate by reflecting it by the light emitting layer, the n-side electrode on the light emitting layer must have high reflectance. This high-reflectance n-side electrode can be realized by using a two-layered structure including an ohmic layer and high-reflection layer as an electrode structure. In this case, however, the interdiffusion of metals between the ohmic layer and the high-reflection layer is a problem.

BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to provide a light emitting element electrode structure capable of simultaneously achieving an ohmic contact and high reflectance and preventing interdiffusion of metals, thereby improving the performance and reliability of the light emitting element and lowering the operating voltage of the element. It is another object of the present invention to suppress scattering and absorption of light in an electrode portion of a light emitting element, thereby increasing the light emission efficiency.

A light emitting element of the present invention comprises a substrate, a light emitting element formed on the substrate to emit light, and a first electrode contacting the light emitting layer. This first electrode includes an ohmic layer in ohmic contact with the light emitting layer, a first barrier layer formed on the ohmic layer to prevent diffusion of metal atoms, and a light reflecting layer formed on the first barrier layer to reflect light.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

FIG. **1** is a view showing a conventional LED;

FIG. **2** is a view showing the first example of a conventional light emitting element;

FIG. **3** is a view showing the second example of a conventional light emitting element;

FIG. **4** is a view showing the third example of a conventional light emitting element;

FIG. **5** is a view showing the fourth example of a conventional light emitting element;

FIG. **6** is a view showing the fifth example of a conventional light emitting element;

FIG. **7** is a view showing an LED of the present invention;

FIG. **8** is a view showing the first embodiment of a light emitting element of the present invention;

FIG. **9** is a view showing one step of a manufacturing method of the present invention;

FIG. **10** is a view showing one step of the manufacturing method of the present invention;

FIG. **11** is a view showing one step of the manufacturing method of the present invention;

FIG. **12** is a view showing one step of the manufacturing method of the present invention;

FIG. **13** is a graph showing the relationship between the electric current and optical output of the light emitting element shown in FIG. **8**;

FIG. **14** is a graph showing the relationship between the thickness and reflectance of a reflecting layer of the light emitting element shown in FIG. **8**;

FIG. **15** is a graph showing the relationship between the thickness of reflectance of an ohmic layer of the light emitting element shown in FIG. **8**;

FIG. **16** is a view showing a modification of the light emitting element shown in FIG. **8**;

FIG. **17** is a view showing the second embodiment of the light emitting element of the present invention;

FIG. **18** is a view showing a modification of the light emitting element shown in FIG. **17**;

FIG. **19** is a view showing the third embodiment of the light emitting element of the present invention;

FIG. **20** is a view showing a modification of the light emitting element shown in FIG. **19**;

FIG. **21** is a view showing the fourth embodiment of the light emitting element of the present invention;

FIG. **22** is a view showing one step of a manufacturing method of the present invention;

FIG. **23** is a view showing one step of the manufacturing method of the present invention;

FIG. **24** is a view showing one step of the manufacturing method of the present invention;

FIG. **25** is a view showing one step of the manufacturing method of the present invention;

FIG. **26** is a view showing a modification of the light emitting element shown in FIG. **21**;

FIG. **27** is a graph showing the relationship between the electric current and optical output of the light emitting element shown in FIG. **21**;

FIG. **28** is a view showing the fifth embodiment of the light emitting element of the present invention;

FIG. **29** is a view showing one step of a manufacturing method of the present invention;

FIG. **30** is a view showing one step of the manufacturing method of the present invention;

FIG. **31** is a view showing one step of the manufacturing method of the present invention;

FIG. **32** is a view showing one step of the manufacturing method of the present invention;

FIG. **33** is a view showing one step of the manufacturing method of the present invention; and

FIG. **34** is a view showing one step of the manufacturing method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Light emitting elements and semiconductor devices using these light emitting elements according to the present invention will be described below with reference to the accompanying drawings.

FIG. **7** shows a lamp type LED of the present invention.

A submount **13** is placed on a lead frame **12**. This submount **13** is made of, e.g., a silicon substrate. On the upper surface of the submount **13**, high-conductivity ohmic electrodes **14-1** and **14-2** having a thickness of about 100 μm are formed.

The positions of these ohmic electrodes **14-1** and **14-2** match the positions of electrodes of a light emitting element **11**. The ohmic electrodes **14-1** and **14-2** are physically separated from each other, and an insulating film **19** is formed only immediately below the ohmic electrode **14-2**. This ohmic electrode **14-2** is electrically connected to the lead frame **12** by a bonding wire **15**. The lower surface of the submount **13** is adhered to the lead frame **12** by a conductive paste **16**.

The light emitting element **11** for emitting violet light is placed on the submount **13**. This light emitting element **11** has p- and n-side electrodes. The light emitting element **11**

is bonded on the submount **13** by flip chip bonding by using AuSn **17**. The light emitting element **11** is covered with an epoxy resin **18**.

FIG. **8** shows the light emitting element shown in FIG. **7**.

An n-GaN layer **21** is formed on a sapphire substrate **20**. On this n-GaN layer **21**, an InGaN active layer **22**, a p-AlGaN cladding layer **23**, and a p-GaN layer **24** are formed. In addition, the n-GaN layer **21** has a recess at the edge of the sapphire substrate **20**. Since the InGaN active layer **22**, the p-AlGaN cladding layer **23**, and the p-GaN layer **24** do not exist on this recess, the n-GaN layer **21** is exposed in this recess.

An n-side electrode **25** is formed on the n-GaN layer **21** in the recess. A p-side electrode **26** is formed on the p-GaN layer **24**. The surfaces of the n-GaN layer **21**, the InGaN active layer **22**, the p-AlGaN cladding layer **23**, and the p-GaN layer **24** are covered with an insulating film **27**, except for regions where the n-side electrode **25** and the p-side electrode **26** are formed.

The n-side electrode **25** has a four-layered structure. This four-layered structure includes a Ti layer **28**, an Al layer **29**, a Ti layer **30**, and an Au layer **31** in this order from the n-GaN layer **21**. The p-side electrode **26** has a five-layered structure. This five-layered structure includes an Ni layer **32**, an Mo layer **33**, an Al layer **34**, a Ti layer **35**, and an Au layer **36** in this order from the p-GaN layer **24**.

The Ni layer **32** is an ohmic layer for achieving an ohmic contact with the p-GaN layer **24**. The thickness of this Ni layer **32** is set to about 4 nm. The Mo layer **33** and the Ti layer **35** function as barrier layers for preventing diffusion of impurities. The Al layer **34** reflects light at high reflectance. The Au layer **36** functions as an overcoat electrode for improving the contact with the submount **13**.

As shown in FIG. **7**, the light emitting element shown in FIG. **8** is bonded by flip chip bonding on the submount **13** with the back side of the sapphire substrate **20** facing up.

In this light emitting element and the LED using the element, when a voltage is applied between the two lead frames **12** an electric current is injected into the InGaN active layer **22** from the p-side electrode **26**. When this electric current is injected into the InGaN layer **22**, the InGaN active layer **22** emits light. This light generated by the LED is spontaneous emission light different from induced emission light. Hence, the light generated by the InGaN layer **22** has no directivity and is radiated in every direction from the InGaN layer **22**.

In the LED shown in FIG. **7** and the light emitting element shown in FIG. **8**, light is extracted from the sapphire substrate **20**.

That is, light traveling from the InGaN active layer **22** to the sapphire substrate **20** is output to the outside of the chip via the n-GaN layer **21** and the sapphire substrate **20** which are transparent to the wavelength of light. On the other hand, light traveling from the InGaN active layer **22** to the p-AlGaN cladding layer **23** is reflected by the Al layer **34** having high reflectance to the wavelength of light. This reflected light is output to the outside of the chip via the n-GaN layer **21** and the sapphire substrate **20**.

In the latter case, the light generated in the InGaN layer **22** makes a round trip along the path passing through the Ni layer **32** and the Mo layer **33**. Note that the Ni layer **32** and the Mo layer **33** are sufficiently thinned to have a low light scattering coefficient and a low light absorption coefficient.

A method of manufacturing the LED shown in FIG. **7** and the light emitting element shown in FIG. **8** will be described below.

First, as shown in FIG. **9**, MO-CVD is used to form an undoped GaN buffer layer on a sapphire substrate **20** and form an n-GaN layer **21** on this buffer layer. Subsequently, an InGaN active layer **22** is formed on the n-GaN layer **21** by MO-CVD or MBE. This InGaN active layer **22** can have an SQW (Single Quantum Well) structure or an MQW (Multiple Quantum Well) structure. In addition, a p-AlGaN cladding layer **23** and a p-GaN layer **24** are formed on the InGaN active layer **22** by MO-CVD.

As shown in FIG. **10**, lithography and anisotropic etching such as RIE (Reactive Ion Etching) are used to remove portions of the p-GaN layer **24**, the p-AlGaN cladding layer **23**, the InGaN active layer **22**, and the n-GaN layer **21**, thereby forming a recess in the edge of the sapphire substrate **20**. After that, an insulating film **27** is formed on the surfaces of the p-GaN layer **24**, the p-AlGaN cladding layer **23**, the InGaN active layer **22**, and the n-GaN layer **21** by CVD.

This recess can also be formed by isotropic etching such as wet etching, rather than by anisotropic etching such as RIE.

As shown in FIG. **11**, lithography and wet etching are used to remove a portion of the insulating film **27** on the n-GaN layer **21**. After that, a Ti layer **28** and an Al layer **29** are formed by vacuum evaporation and lift-off. Also, the structure is annealed in a nitrogen atmosphere at about 600° C. to form an ohmic contact between the n-GaN layer **21** and the Ti layer **28**.

As shown in FIG. **12**, lithography and wet etching are used to remove a portion of the insulating film **27** on the p-GaN layer **24**. After that, an Ni layer **32** about 4 nm thick, an Mo layer **33** about 1 nm thick, and an Al layer **34** about 500 nm thick are formed by vacuum evaporation and lift-off.

If flash annealing is performed at a temperature of 400° C. to 780° C. (preferably 450° C.) for 20 sec immediately after the Ni layer **32** is formed, an ohmic contact between the p-GaN layer **24** and the Ni layer **32** can be easily formed.

It is, however, not particularly necessary to perform this flash annealing if no natural oxide film exists in a portion between the Ni layer **32** and the p-GaN layer **24** and if this portion is satisfactorily clean.

Subsequently, as shown in FIG. **8**, vacuum evaporation and lift-off are used to form Ti layers **30** and **35** about 100 nm thick and Au layers **31** and **36** about 1,000 nm thick on the Al layers **29** and **34**, respectively. To improve adhesion between a plurality of layers forming electrodes **25** and **26**, flash annealing is performed at a temperature of about 200° C. or more (favorably about 250° C.) for 20 sec.

The temperature of this flash annealing is set to be lower than that of flash annealing performed in the step shown in FIG. **12**, if flash annealing is performed in the step shown in FIG. **12**.

A semiconductor element of the present invention is completed by the above method.

The semiconductor element manufactured by the above method is packaged to form an LED (semiconductor device) of the present invention.

That is, as shown in FIG. **7**, the light emitting element **11** is mounted on the submount **13** having the ohmic electrodes **14-1** and **14-2** made of an Au layer about 3 μm thick by flip chip bonding. Consequently, the n-side electrode **25** is connected to the electrode **14-1** by the bump (e.g., AuSn, PbSn, AgSn) **17**, and the p-side electrode **26** is connected to the electrode **14-2** by the bump **17**.

The submount **13** on which the light emitting element **11** is mounted is adhered to the cup type lead frame **12** by using the conductive paste **16**. In this state, the electrode **14-1** is electrically connected to the cup type lead frame **12**. Also,

the electrode **14-2** and the lead frame **12** are electrically connected by wire bonding. Furthermore, the light emitting element **11** is covered with the epoxy resin **18**.

If the light emitting element **11** is formed using an n-GaN substrate as a conductive substrate, rather than a sapphire substrate, the n-side electrode can also be formed on the back side of this n-GaN substrate.

The LED of the present invention is completed by the above method.

In the light emitting element, the LED, and the methods of fabricating them, the p-side electrode **26** has the Ni layer **32** for forming an ohmic contact with the p-GaN layer **24**, the Mo layer **33** having a barrier function of blocking impurity diffusion, and the Al layer **34** having high reflectance to light generated in the element.

Generally, an ohmic contact to a GaN layer is difficult to form when metals such as Al and Ag having high reflectance to visible light are used. Therefore, the p-side electrode is conventionally composed of an ohmic layer for forming an ohmic contact and a high-reflection layer for reflecting light generated in the element.

When an LED having this electrode structure is continuously operated, however, interdiffusion of metal atoms occurs between the ohmic layer and the high-reflection layer owing to the influence of heat. This raises the forward voltage of the light emitting diode and readily deteriorates the element. And the electrode sometimes comes off.

By contrast, in the present invention the barrier layer (e.g., Mo layer) **33** made of a high-melting metal is formed between the Ni layer **32** as an ohmic layer and the Al layer **34** as a high-reflection layer. This barrier layer prevents interdiffusion of metal atoms between the ohmic layer and the high-reflection layer. Accordingly, the present invention can prevent a rise of the operating voltage of the LED.

The ohmic layer (Ni layer **32**) and the barrier layer (Mo layer **33**) are made of materials substantially opaque to light generated in the element. By decreasing the thicknesses of these layers, the light reflectance of the high-reflection layer (Al layer **34**) can be increased.

FIG. **13** shows the emission characteristic of the GaN violet type LED of the present invention.

This emission characteristic is represented by the relationship between the electric current injected into the LED and its optical output (emission intensity). Referring to FIG. **13**, the solid line indicates the emission characteristic of the GaN violet type LED according to the present invention, and the broken line indicates that of a conventional LED.

As shown in FIG. **13**, when the same electric current is injected into these LEDs, the optical output of the LED according to the present invention is about 1.7 times that of the conventional LED. For example, when the electric current injected into the LEDs is 20 mA (voltage 4.3 V), the optical output of the conventional LED is about 4.0 mw, whereas the optical output of the LED of the present invention is about 6.9 mW (emission wavelength $\lambda p=450$ nm).

Also, after the LED of the present invention was operated for 1,000 hr at room temperature by using a driving current of 20 mA, the optical output reduced to about 80% of the initial value. This is a very good result compared to the conventional LED and indicates that the reliability of the LED of the present invention improved.

FIG. **14** shows the relationship between the thickness of the Mo layer as a barrier layer and the light reflectance of the Al layer as a high-reflection layer.

In this relationship, the thickness of the Ni layer as an ohmic layer is fixed to 4 nm, and the thickness of the Al layer as a high-reflection layer is fixed to 100 nm.

FIG. **15** shows the relationship between the thickness of the Ni layer as an ohmic layer and the Al layer as a high-reflection layer.

In this relationship, the thickness of the Mo layer as a barrier electrode is fixed to 1 nm, and the thickness of the Al layer as a high-reflection layer is fixed to 100 nm.

As shown in FIGS. **14** and **15**, the light reflectance of the Al layer largely depends upon the thicknesses of the barrier layer and the ohmic layer; the smaller the thicknesses of these layers, the higher the light transmittance. In particular, the thickness of the ohmic layer into which light generated in the InGaN active layer initially enters is preferably as small as possible. For example, when this ohmic layer is made of Ni, its thickness is set to 10 nm or less.

The ohmic layer can be formed using materials such as Pt, Mg, Zn, Be, Ag, Au, and Ge and compounds consisting primarily of these materials, in addition to Ni. Also, the barrier layer can be formed using materials such as W, Pt, Ni, Ti, Pd and V and compounds consisting primarily of these materials, in addition to Mo.

These ohmic layer and barrier layer can be integrated into a single layer if they are formed using the same material (Ni or Pt).

In the light emitting element of the present invention, the Ti layer **35** as a barrier layer and the Au layer **36** as an overcoat layer are formed on the Al layer **34** as a high-reflection layer. Commonly, a conductor pattern of Au is written on a submount on which a light emitting element is to be mounted. A light emitting element is adhered onto this conductor pattern.

If, however, a high-reflection layer made of Al or Ag is brought into direct contact with the Au conductor pattern, a high-resistance layer may be formed on the bonding surface between them, or the bonding power between them weakens.

In the present invention, therefore, an overcoat layer made of the same material as the conductor pattern (e.g., Au) on the submount is formed, thereby preventing the generation of a high-resistance layer and increasing the bonding power between the light emitting element and the submount.

In addition, in the present invention the barrier layer (Ti layer **35**) made of a high-melting metal is formed between the overcoat layer and the high-reflection layer. Since this barrier layer prevents diffusion of metal atoms from the overcoat layer to the high-reflection layer, the bonding power between the overcoat layer and the conductor pattern can be increased.

When the conductor pattern and the high-reflection layer are made of the same material, it is of course unnecessary to form a high-melting-material barrier layer between the overcoat layer and the high-reflection layer.

This barrier layer interposed between the overcoat layer and the high-reflection layer can be formed using materials such as W, Mo, Pt, Ni, Ti, Pd, and V and compounds consisting primarily of these materials, in addition to Ti.

Furthermore, in the present invention the light emitting element is not in direct contact with the lead frame but is mounted on the lead frame via the submount. In this structure, heat generated in the light emitting element is efficiently radiated via the submount. This can increase the heat radiation efficiency and improve the reliability of the LED.

FIG. **16** shows a modification of the light emitting element shown in FIG. **8**.

On an n-GaP substrate **40**, an n-InGaAlP adhesive layer **41** and an n-InGaAlP cladding layer **42** are formed. On this n-InGaAlP cladding layer **42**, an InGaAlP active layer **43** is formed. As InGaAlP, a direct transition type band structure is used to obtain red light to green light, unlike AlGaAs for which an indirect transition type band structure is used to obtain green light.

On the InGaAlP active layer **43**, a p-InGaAlP cladding layer **44** and a p-GaAs contact layer **45** are formed. A p-side electrode **47** is formed on the p-GaAs contact layer **45**, and an n-side electrode **48** is formed on the back side of the n-GaP substrate **40**. The surfaces of the n-InGaAlP cladding layer **42**, the InGaAlP active layer **43**, the p-InGaAlP cladding layer **44**, and the p-GaAs contact layer **45** are covered with an insulating film **46**, except for a region where the p-side electrode **47** is formed.

The p-side electrode **47** includes an AuZn layer **49**, an Mo layer **50**, an Al layer **51**, a Ti layer **52**, and an Au layer **53**. The AuZn layer **49** forms an ohmic contact with the p-GaAs contact layer **45**. The Mo layer **50** is a barrier layer having a function of preventing interdiffusion of metal atoms. The Al layer **51** is a high-reflection layer having a function of reflecting light generated in the element at high reflectance. The Ti layer **52** is a barrier layer having a function of preventing interdiffusion of metal atoms. The Au layer **53** is an overcoat layer for improving the contact with a submount.

As shown in FIG. **7**, this light emitting element shown in FIG. **16** is mounted on a submount **13** by flip chip bonding, with the back side of the n-GaP substrate **40** facing up.

In this modification, the n-side electrode **48** is formed on the back side of the n-GaP substrate **40**. That is, this n-side electrode **48** is formed on the surface different from the surface on which the p-side electrode **47** is formed. Hence, the n-side electrode and the lead frame are electrically connected directly by a bonding wire. However, the n-side electrode **48** and the p-side electrode **47** can also be formed on the same surface.

In this light emitting element as described above, the barrier layer (e.g., an Mo layer) made of a high-melting metal is formed between the ohmic layer (e.g., an AuZn layer) and the high-reflection layer (e.g., an Al layer). Since this barrier layer prevents interdiffusion of metal atoms between the ohmic layer and the high-reflection layer, a rise of the operating voltage of the LED can be prevented. Consequently, effects similar to those of the light emitting element shown in FIG. **8** can be obtained.

A method of fabricating the p-side electrode **47** of the light emitting element according to the present invention is the same as the method of fabricating the p-side electrode of the light emitting element shown in FIG. **8**, so a detailed description thereof will be omitted.

FIG. **17** shows the second embodiment of the light emitting element of the present invention.

This light emitting element relates to a GaN violet type LED.

Compared to the light emitting element (FIG. **8**) explained in the above first embodiment, the characteristic feature of the light emitting element according to this embodiment is the structure of a p-side electrode **26**.

An Ni layer **32** as an ohmic layer in contact with a p-GaN layer **24** is made up of a plurality of dots (islands) arranged into arrays. An Mo layer **33** as a barrier layer is formed on the Ni layer **32** and the p-GaN layer **24**. Accordingly, the p-GaN layer **24** is in contact with both the Ni layer **32** and the Mo layer **32**.

Of light generated in an InGaN active layer **22**, a portion of light heading to a p-AlGaN cladding layer **23** passes through the Ni layer **32** and the Mo layer **33** with low scattering and low absorption. Another portion of the light heading to the p-AlGaN cladding layer **23** passes only through the Mo layer **33** without passing through the Ni layer **32**.

In this light emitting element as described above, the ohmic layer (Ni layer) for forming an ohmic contact with the p-GaN layer does not cover the entire surface of the p-side electrode; this ohmic layer partially covers the p-side electrode as, e.g., a plurality of dots (islands) arranged into arrays. Therefore, in a region where this ohmic layer exists, an ohmic contact is formed between the p-side electrode and the p-GaN layer. In a region where the ohmic layer does not exist, only the barrier layer is formed between the p-GaN layer and the Al layer as a high-reflection layer, thereby shortening the distance between the two layers.

In a region where the ohmic layer is absent, therefore, the light transmittance can be increased accordingly. As a consequence, the light extraction efficiency can be increased.

The ohmic layer can be formed using materials such as Ni, Pt, Mg, Zn, Be, Ag, Au, and Ge and compounds consisting primarily of these materials. The barrier layer can be formed using materials such as Mo, W, Pt, Ni, Ti, Pd and V and compounds consisting primarily of these materials.

The ohmic layer and the barrier layer can also be formed using the same material (e.g., Ni or Pt).

FIG. **18** shows a modification of the light emitting element shown in FIG. **17**.

On an n-GaP substrate **40**, an n-InGaAlP adhesive layer **41** and an n-InGaAlP cladding layer **42** are formed. On this n-InGaAlP cladding layer **42**, an InGaAlP active layer **43** is formed.

On the InGaAlP active layer **43**, a p-InGaAlP cladding layer **44** and a p-GaAs contact layer **45** are formed. A p-side electrode **47** is formed on the p-GaAs contact layer **45**, and an n-side electrode **48** is formed on the back side of the n-GaP substrate **40**. The surfaces of the n-InGaAlP cladding layer **42**, the InGaAlP active layer **43**, the p-InGaAlP cladding layer **44**, and the p-GaAs contact layer **45** are covered with an insulating film **46**, except for a region where the p-side electrode **47** is formed.

The p-side electrode **47** includes an AuZn layer **49**, an Mo layer **50**, an Al layer **51**, a Ti layer **52**, and an Au layer **53**. The AuZn layer **49** forms an ohmic contact with the p-GaAs contact layer **45**. The Mo layer **50** is a barrier layer having a function of preventing interdiffusion of metal atoms. The Al layer **51** is a high-reflection layer having a function of reflecting light generated in the element at high reflectance. The Ti layer **52** is a barrier layer having a function of preventing interdiffusion of metal atoms. The Au layer **53** is an overcoat layer for improving the contact with a submount.

The AuZn layer **49** as an ohmic layer is made up of a plurality of dots (islands).

As shown in FIG. **7**, this light emitting element shown in FIG. **18** is mounted on a submount **13** by flip chip bonding, with the back side of the n-GaP substrate **40** facing up.

In this modification, the n-side electrode **48** is formed on the back side of the n-GaP substrate **40**. That is, this n-side electrode **48** is formed on the surface different from the surface on which the p-side electrode **47** is formed. Hence, the n-side electrode and the lead frame are electrically connected directly by a bonding wire. However, the n-side electrode **48** and the p-side electrode **47** can also be formed on the same surface.

In this light emitting element as described above, the barrier layer (e.g., an Mo layer) made of a high-melting metal is formed between the ohmic layer (e.g., an AuZn layer) and the high-reflection layer (e.g., an Al layer). Since this barrier layer prevents interdiffusion of metal atoms between the ohmic layer and the high-reflection layer, a rise of the operating voltage of the LED can be prevented. Consequently, effects similar to those of the light emitting element shown in FIG. **8** can be obtained.

FIG. **19** shows the third embodiment of the light emitting element of the present invention.

On a sapphire substrate **20**, an n-GaN layer **21** and a light emitting layer **55** are formed. For example, this light emitting layer **55** includes, as shown in FIG. **8**, an InGaN active layer **22** on the n-GaN layer **21**, a p-AlGaN cladding layer **23** on the InGaN active layer **22**, and a p-GaN layer **24** on the p-AlGaN cladding layer **23**.

A p-side electrode **26** is formed on the light emitting layer **55**. For example, this p-side electrode **26** includes, as shown in FIG. **8**, an ohmic layer **32**, a barrier layer **33**, a high-reflection layer **34**, a barrier layer **35**, and an overcoat layer **36**.

The p-side electrode **26** is placed in a central portion on the upper surface of the light emitting layer **55**. Also, an n-side electrode **25** is placed at the edge on the upper surface of the n-GaN layer **21** to surround the light emitting layer **55**.

The LED shown in FIG. **7** is completed by mounting the above light emitting element on a lead frame by using a submount and covering the light emitting element with an epoxy resin.

This light emitting element can achieve the following effects in addition to the effects of the light emitting elements of the aforementioned first and second embodiments.

First, since the p-side electrode is positioned in the central portion of the chip, the light emitting element is readily aligned when mounted on the submount. This can facilitate the fabrication of the LED and thereby improve the throughput.

Second, since the n-side electrode surrounds the light emitting layer, an electric current flowing from the p-side to the n-side electrode is evenly injected into the active layer. Hence, the light emitting layer can generate light with high efficiency.

FIG. **20** shows a modification of the light emitting element shown in FIG. **19**.

The characteristic feature of the light emitting element of this embodiment is that the shape of a light emitting layer **55** is different from that of the light emitting element shown in FIG. **19**.

In the light emitting element shown in FIG. **19**, the light emitting layer **55** is formed in a wide region including a region immediately below the p-side electrode **26**, and the shape of this light emitting layer **55** is a square similar to that of the chip. By contrast, in the light emitting element shown in FIG. **20**, the light emitting layer **55** is formed only in a region immediately below the p-side electrode **26** and a narrow region surrounding that region, and the shape of this light emitting layer **55** is a circle similar to that of the p-side electrode.

In the light emitting element of this embodiment, the light emitting region is limited. Therefore, the light emitting element of this embodiment can be used as a signal source of an optical fiber system or in a system required to operate at high speed.

In the light emitting elements shown in FIGS. **19** and **20**, the shapes of the n-side electrode **25**, the p-side electrode **26**, and the light emitting element **55** can be variously changed. For example, the p-side electrode **26** can be a square, or the n-side electrode **25**, the p-side electrode **26**, and the light emitting layer **55** can take shapes other than a circle and square.

The light emitting element according to the third embodiment described above is applicable to, e.g., a GaN light emitting element, GaAs light emitting element, and GaP light emitting element. This light emitting element is also applicable to an LED which uses a conductive substrate instead of a sapphire substrate.

FIG. **21** shows the fourth embodiment of the light emitting element of the present invention.

The light emitting element of this embodiment is applied to a GaAs light emitting element and GaP light emitting element, and generates red light having a wavelength of, e.g., 620 nm.

On a p-GaP substrate **60**, a p-InGaAlP adhesive layer **61** and a p-InAlP cladding layer **62** are formed. An InGaAlP active layer **63** is formed on the p-InAlP cladding layer **62**. An n-type InAlP cladding layer **64** is formed on the InGaAlP active layer **63**, and an n-InGaAlP window layer **65** is formed on this n-type InAlP cladding layer **64**. Also, an n-GaAs contact layer **66** is formed on the n-InGaAlP window layer **65**, and an n-side electrode **67** is formed on the n-GaAs contact layer **66**. In addition, a p-side electrode **68** and a light reflecting film **69** are formed on the back side of the p-GaP substrate **60**.

A method of manufacturing the light emitting element shown in FIG. **21** will be described below.

First, as shown in FIG. **22**, MO-CVD is used to form an etching stopper (e.g., InGaP) **71**, an n-GaAs contact layer **66** about 0.1 μm thick, an n-$In_{0.5}Ga_{0.15}Al_{0.35}P$ window layer **65** about 0.5 μm thick, and an n-$In_{0.5}Al_{0.5}P$ cladding layer **64** about 1 μm thick in this order on an n-GaAs substrate **70**.

Subsequently, MO-CVD or MBE is used to form an undoped $In_{0.5}Ga_{0.1}Al_{0.4}P$ active layer **63** about 0.2 μm thick on the n-InAlP cladding layer **64**, and form a p-$In_{0.5}Al_{0.5}P$ cladding layer **62** about 1 μm thick and a p-$In_{0.5}Ga_{0.15}Al_{0.35}P$ adhesive layer **61** about 0.05 μm thick on the undoped InGaAlP active layer **63**.

Examples of the gallium material are triethylgallium (TEG: $Ga(C_2H_5)_3$) and trimethylgallium (TMG: $Ga(CH_3)_3$). Examples of the aluminum material are triethylaluminum (TEA: $Al(C_2H_5)_3$) and trimethylaluminum (TMA: $[Al(CH_3)_3]_2$). Examples of the indium material are triethylindium (TEI: $In(C_2H_5)_3$) and trimethylindium (TMI: $In(CH_3)_3$). An example of the phosphorous material is tertiary-butylphosphine (TBP: $C_4H_9PH_2$).

As an n-impurity, Si, Te, or the like is used. As a p-impurity, Zn, Be, or the like is used.

Subsequently, as shown in FIG. **23**, a p-GaP substrate **60** about 200 μm thick is adhered onto the p-InGaAlP adhesive layer **61** by thermal contact bonding. Before this adhesion, the adhesion surfaces of the p-InGaAlP adhesive layer **61** and the p-GaP substrate **60** are well cleaned.

Also, the n-GaAs substrate **70** is removed by etching.

As shown in FIG. **24**, the etching stopper **71** is removed.

As shown in FIG. **25**, the n-GaAs contact layer **66** is patterned by photolithography and etching.

After that, an n-side electrode **67** is formed on the n-GaAs contact layer **66**, and a p-side electrode **68** and a light reflecting layer (e.g., Au) **69** are formed on the back side of the p-GaP substrate **70**. In this manner, the light emitting element shown in FIG. **21** is obtained.

The lamp type LED is completed by mounting the light emitting element shown in FIG. **21** on a lead frame and covering this light emitting element with an epoxy resin.

This LED emits red light when an electric current flowing from the p-side to the n-side electrode is injected into the InGaAlP active layer **63**.

Of the red light having a wavelength of 620 nm generated in the InGaAlP active layer **63**, light heading to the n-InAlP cladding layer **64** and the n-InGaAlP window layer **65** is directly emitted to the outside of the chip. Of the red light having a wavelength of 620 nm generated in the InGaAlP active layer **63**, light heading to the p-GaP substrate **60** is transmitted through the transparent p-GaN substrate **60** and reaches the p-side electrode **68** and the light reflecting layer **69**. This light is reflected by the light reflecting layer **69**. The reflected light reaches the n-InAlP cladding layer **64** and the n-InGaAlP window layer **65** and is emitted to the outside of the chip.

When the light emitting element of this embodiment was mounted in a package having an emission angle of 10° and operated by a driving current of 20 mA, the optical output rose to 1.2 times (17 cd) that of a conventional light emitting element.

This light emitting element is applied to a GaAs or GaP light emitting element having a flip chip structure. Also, the light emitting element of this embodiment can reduce the loss produced in the alloy layer between the transparent substrate and the electrode, because the light reflecting layer is formed in a portion of the back side of the transparent substrate. As a consequence, in a region where the light reflecting layer is present, light can be efficiently reflected and emitted to the outside of the chip.

The material of this light reflecting layer is, e.g., Au. This is so because Au has high reflectance to light having a wavelength of 620 nm, which is generated in the InGaAlP active layer.

Table 1 shows the values of reflectance R and thermal conductivity k of metal materials.

Assume that these metal materials are in contact with the GaP substrate, and that the reflectance is a numerical value with respect to light having a wavelength of 620 nm. Refractive index n of GaP at this wavelength is 3.325. Assume also that the thermal conductivity is a numerical value at a temperature of 300K.

TABLE 1

METAL MATERIAL	REFLECTANCE R [%]	THERMAL CONDUCTIVITY k [W/m · K]
Al	77.6	237
Cr	29.1	90.3
Co	37.4	99.2
Cu	87.7	398
Au	92.1	315
Hf	13	23
Mo	20.4	138
Ni	37.5	90.5
Nb	18	53.7
Os	5.3	87.3
Ag	88.2	427
Ta	20.3	57.5
Ti	25.8	21.9
W	12	178

The characteristics required for a light reflecting layer are high reflectance and high thermal conductivity. In a light emitting element using InGaAlP, a lowering of the emission efficiency by heat is significant. Therefore, efficiently radiating heat generated near the active layer to the outside of the element is important. For this purpose, as is apparent from Table 1, a material having high reflectance and high thermal conductivity, e.g., Au, Ag, Cu, or Al, is used as a light reflecting layer of a light emitting element.

Referring to FIG. **21**, the area of the p-side electrode **68** and the area of the light reflecting layer **69** have the following relationship. That is, when the area of the p-side electrode **68** is made larger than that of the light reflecting layer **69**, the contact resistance decreases, but the light reflection efficiency lowers; when the area of the light reflecting layer **69** is made larger than that of the p-side electrode **68**, the light reflection efficiency rises, but the contact resistance increases.

In the light emitting element of this embodiment, the area ratio of the p-side electrode **68** to the light reflecting layer **69** is set at, e.g., 1:1. However, this ratio can be appropriately changed in accordance with the specification of a light emitting element. For example, in a light emitting element in which a rise of the contact resistance is of no problem, the area of the light reflecting layer **69** is made larger than that of the p-side electrode **68** to raise the light reflection efficiency.

FIG. **26** shows a modification of the light emitting element shown in FIG. **21**.

The light emitting element of this modification is characterized in that the structure of a light reflecting layer is different from that of the light emitting element shown in FIG. **21**.

A light reflecting layer **69** on the back side of a p-GaP substrate **60** is composed of an Si layer **72** and an Al_2O_3 layer **73**. The thicknesses of the Si layer **72** and the Al_2O_3 layer are so set as to be $\lambda/4n$ (n indicates the refractive indices of Si and Al_2O_3 with respect to the wavelength of light generated in the active layer) with respect to a wavelength λ of light generated in the active layer.

The Si layer **72** and the Al_2O_3 **73** have a large refractive index difference, and the absorption coefficient of the Si layer **72** having a high refractive index is small. Therefore, the light reflecting layer **69** can achieve high reflectance. However, the Al_2O_3 layer **68** having a low refractive index has small thermal conductivity and hence deteriorates the thermal characteristics of the element.

FIG. **27** shows the relationship between the electric current and the optical output of the light emitting element shown in FIG. **21**.

Referring to FIG. **27**, line ① corresponds to the light emitting element shown in FIG. **21**; line ②, the light emitting element shown in FIG. **26**; and line ③, a conventional light emitting element.

According to this relationship, the light emitting element shown in FIG. **21** is most superior in optical output and durability. The optical output of the light emitting element shown in FIG. **26** saturates when the injection current increases under the influence of low thermal conductivity of Al_2O_3. However, when the injection current is 150 mA or less, the optical output of this light emitting element shown in FIG. **26** is higher than that of the conventional light emitting element.

When the driving current is 20 mA, the characteristic of the light emitting element shown in FIG. **26** is substantially the same as that of the light emitting element shown in FIG. **21**. Accordingly, it is well significant to use the light emitting element of this modification as an LED.

FIG. **28** shows the fifth embodiment of the light emitting element of the present invention.

This embodiment relates to a light emitting element which generates 620 nm red light in a GaAs light emitting element and a GaP light emitting element.

A light emitting layer **81** is formed on a portion of an n-GaP substrate **80**. This light emitting layer **81** includes an n-InGaAlP contact layer **82**, an n-InAlP cladding layer **83**, an InGaAlP active layer **84**, a p-InAlP cladding layer **85**, and a p-InGaAlP contact layer **86**.

An undoped GaP current limiting layer **87** is formed on the other portion (a region where the light emitting layer **81** is not formed) of the n-GaP substrate **80**. A p-GaP layer **88** is formed on the light emitting layer **81** and the undoped GaP current limiting layer **87**. A p-side electrode **89** is formed on the p-GaP layer **88**. An n-side electrode **90** and a light reflecting layer **91** are formed on the back side of the n-GaP substrate **80**.

Note that the n-side electrode **90** is positioned immediately below the light emitting layer **81**.

A method of manufacturing the light emitting element shown in FIG. **28** will be described below.

First, as shown in FIG. **29**, MO-CVD is used to form an n-$In_{0.5}Ga_{0.15}Al_{0.35}P$ contact layer **82**, an n-$In_{0.5}Al_{0.5}P$ cladding layer **83**, an $In_{0.5}Ga_{0.1}Al_{0.4}P$ active layer **84**, a p-$In_{0.5}Al_{0.5}P$ cladding layer **85**, and a p-$In_{0.5}Ga_{0.15}Al_{0.35}P$ contact layer **86** in this order on an n-GaAs substrate **92**. Subsequently, MO-CVD is used to form an undoped GaAs protective layer **93** and an SiO_2 mask layer **94** in this order on the p-$In_{0.5}Ga_{0.15}Al_{0.35}P$ contact layer **86**.

Next, as shown in FIG. **30**, the SiO_2 mask layer **94** is patterned by photolithography and wet etching. This SiO_2 mask layer **94** is used as a mask to etch the GaAs protective layer **93**, the p-$In_{0.5}Ga_{0.15}Al_{0.35}P$ contact layer **86**, the p-$In_{0.5}Al_{0.5}P$ cladding layer **85**, the $In_{0.5}Ga_{0.1}Al_{0.4}P$ active layer **84**, the n-$In_{0.5}Al_{0.5}P$ cladding layer **83**, and the n-$In_{0.5}Ga_{0.15}Al_{0.35}P$ contact layer **82** by RIE, thereby forming a ridge-shaped light emitting layer **81**.

As shown in FIG. **31**, an undoped GaP current limiting layer **87** is formed on the n-GaAs substrate **92** by CVD.

As shown in FIG. **32**, a p-GaP layer **88** is formed on the light emitting layer **81** and the undoped GaP current limiting layer **87** by CVD. After that, the n-GaAs substrate **92** is entirely etched away to form a device as shown in FIG. **33**.

As shown in FIG. **34**, an n-GaP substrate **80** is bonded to the device shown in FIG. **33**.

After that, as shown in FIG. **28**, a p-side electrode **89** is formed on the p-GaP layer **88**, and an n-side electrode **90** and a light reflecting layer **91** are formed on the back side of the n-GaP substrate **80**.

Note that the light emitting layer **81** is positioned in a central portion of the n-GaP substrate **80** (or the chip) and surrounded by the undoped GaP current limiting layer **87**.

Of red light generated in the InGaAlP active layer **84** of this light emitting element, light traveling to the p-side electrode is emitted to the outside of the chip through the p-InAlP cladding layer **85**, the p-InGaAlP contact layer **86**, and the p-GaP layer **88**. Of the red light generated in the InGaAlP active layer **84**, light heading to the n-GaP substrate **80** is reflected by the light reflecting layer **91** through the n-GaP substrate **80** which is a transparent substrate. This reflected light travels to the p-side electrode and is emitted to the outside of the chip.

In this structure, the n-side electrode **90** is positioned immediately below the InGaAlP active layer **83**, and the light reflecting layer **91** is positioned immediately below the GaP current limiting layer **87**. That is, light heading to the n-GaP substrate **80** is reflected by the light reflecting layer **91**. Consequently, the reflected light is emitted to the outside of the chip through the GaP current limiting layer **87** whose bandgap energy is larger than its emission energy, without passing through the light emitting layer **81**.

Since the reflected light does not pass through the light emitting layer **81**, this reflected light is not again absorbed by the light emitting layer **81**. Accordingly, the light emitting element of this embodiment can achieve sufficiently high light extraction efficiency. For example, when the light emitting element mounted in a package having an emission angle of 10° is operated with a driving current of 20 mA, the optical output is 1.4 times (about 20 cd) that of a conventional light emitting element.

In each of the first, second, and third embodiments of the light emitting element of the present invention, light generated in the active layer and traveling to the p-side electrode is reflected by the internal high-reflection layer of the p-side electrode, so the entire light is extracted to the outside of the chip from the back side of the substrate. In this arrangement, the electrode structure of the p-side electrode includes at least an ohmic layer for an ohmic contact, a barrier layer for preventing diffusion of metal impurities, and a high-reflection layer for reflecting light generated in the active layer with high reflectance.

The barrier layer is made of a high-melting material and prevents interdiffusion of metal atoms caused by heat between the ohmic layer and the high-reflection layer. Also, since the thicknesses of the ohmic layer and barrier layer are made as small as possible, the light absorption loss in these ohmic layer and barrier layer can be minimized. Therefore, in this p-side electrode it is possible to realize an ohmic contact and high light reflectance at the same time and suppress a rise of the operating voltage by heat.

As a consequence, the light emitting element and the semiconductor device using the same according to the present invention can realize high reliability and high performance. When the ohmic layer is made up of a plurality of dots (islands) arranged into arrays, it is possible to realize not only an ohmic contact but also high light extraction efficiency by high reflectance in a region where no ohmic layer exists, because absorption and loss of light can be reduced by the amount of ohmic layer.

In each of the fourth and fifth embodiments of the light emitting element of the present invention, light generated in the active layer and traveling to the substrate is reflected by the light reflecting layer, so the entire light is extracted to the outside of the chip from the surface of the p-GaP layer on the p-side electrode side.

Also, the electrode and the light reflecting layer are alternately arranged on the back side of the substrate. In a region where the electrode is present, scattering and absorption of light occur; in a region where the light reflecting layer is present, light is reflected with high efficiency. Accordingly, the light emitting element of the present invention can increase the light extraction efficiency and improve the performance of both the element and the semiconductor device using the element, compared to conventional light emitting elements.

Furthermore, the light emitting layer is formed in the shape of a ridge and surrounded by a transparent material (undoped GaP). In this structure, an electrode is placed immediately below the light emitting layer, and a light reflecting layer is placed immediately below the transparent material. Consequently, it is possible to prevent an event in which light reflected by the light reflecting layer is again absorbed in the light emitting layer, and to increase the light extraction efficiency.

As has been explained above, the electrode structure of the present invention can realize an ohmic contact and high light reflectance at the same time, and can also prevent interdiffusion of metal atoms between a plurality of layers

forming the electrode. This makes it possible to increase the external quantum efficiency of a light emitting element, lower the operating voltage, and improve the reliability.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A light emitting element comprising:

a substrate;

a light emitting layer formed on said substrate to emit light, wherein said light emitting layer includes a first semiconductor layer of a first conductivity type, an active layer formed on said first semiconductor layer to emit the light and a second semiconductor layer of a second conductivity type formed on said active layer;

a first electrode contacting said second semiconductor layer;

a second electrode contacting said substrate and being only located at a place which is below the center of the light emitting layer, such that a center line drawn vertically through the light emitting layer will pass through the second electrode; and

a light reflecting layer contacting said substrate and being only located at a place which is along an edge of said substrate.

2. The light emitting element according to claim **1**, wherein an area of said light reflecting layer is larger than that of said second electrode.

3. The light emitting element according to claim **1**, wherein said substrate is a conductive substrate.

4. The light emitting element according to claim **3**, wherein said substrate includes Ga.

5. The light emitting element according to claim **1**, wherein said first semiconductor layer and said second semiconductor layer include Ga.

6. The light emitting element according to claim **1**, wherein said first electrode is located at a place except a place which is above the center of said substrate.

7. The light emitting element according to claim **1**, further comprising a current limiting layer formed on said substrate, wherein said current limiting layer is located at a place except a place at which said light emitting layer is formed.

8. The light emitting element according to claim **7**, wherein said light reflecting layer is located at a place which is below the current limiting layer.

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